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ABSTRACT

This shop tools manual is one of a series of power mechanics texts and visual aids on servicing of automotive and off-the-road equipment. Materials provide basic information and illustrations for use by vocational students and teachers as well as shop servicemen and laymen. Sections describe the use of the following tools: screwdrivers, hammers, pliers, wrenches, chisels, punches, files, hacksaws, vises, clamps, twist drills, taps and dies, screw extractors, pullers, magnetic pick-up tools, inspection mirrors, tubing cutters, soldering equipment, feeler gauges, micrometers, dial indicators, spring testers, pressure gauges, and speed-measuring tools. The manual concludes with test questions. Appended material includes tables of weights and measures and the test question answers. (A supplementary 35mm slide set is also available--see availability note.) (LRA)

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Shop Tools

JOHN DEERE

FOS

FUNDAMENTALS OF SERVICE

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TO THE READER

PURPOSE OF THIS MANUAL

The main purpose of this manual is to train the reader in the use of shop tools. For the novice, it is a training guide; for the journeyman, a reference. The story is written in simple form using many illustrations so that it can be easily understood.

WHAT IS "FUNDAMENTALS OF SERVICE"?

This manual is part of a series of texts and visuals called "Fundamentals of Service", or "FOS". These materials are basic information in power mechanics for use by teachers as well as shop servicemen and the layman. All types of modern equipment are covered — both automotive and off-the-road. Emphasis is on theory of operation, diagnosis, and repair.

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SHOP TOOLS

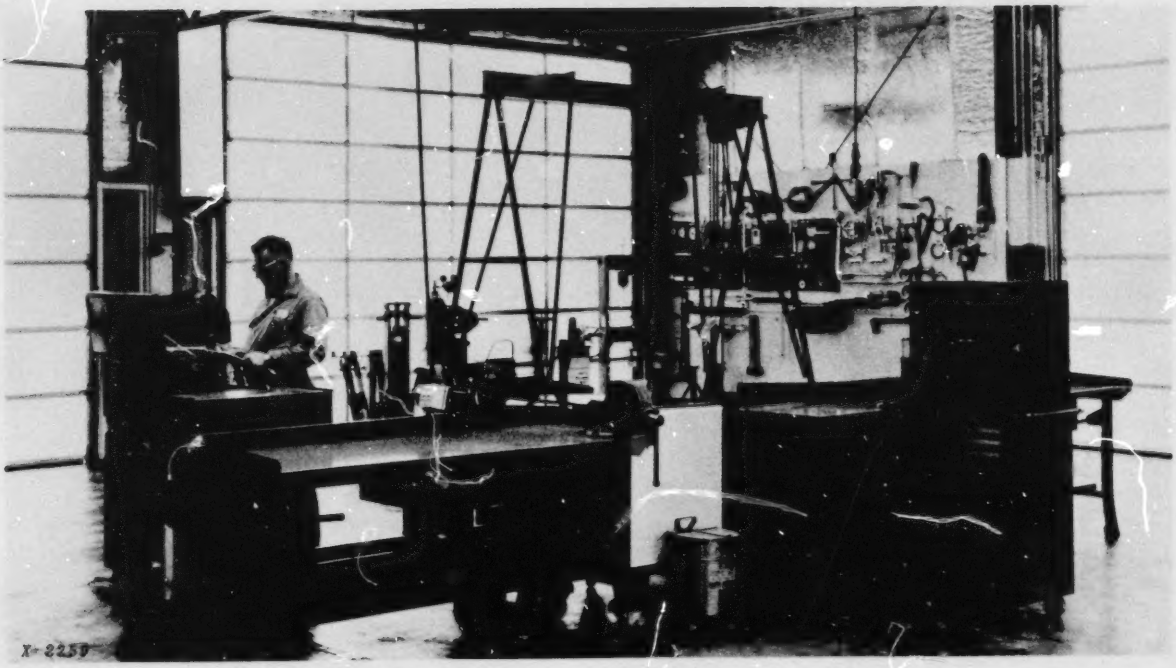


Fig. 1 — Tools Don't Make The Serviceman — But They Help

INTRODUCTION

Tools don't make the serviceman — but they help. Knowing how to use and care for them will put you a step ahead of the crowd.

To get the best out of your tools, remember these three rules:

1. **Purchase only good tools**
2. **Keep tools in safe condition**
3. **Use the right tool for the job**

A serviceman is known by the tools he uses, so buy the best, keep them in good shape, and use them right.

In this chapter, we'll cover the tools shown in the box at right.

Screwdrivers	*Pullers*
Hammers	*Magnetic Pick-Up Tools*
Pliers	*Inspection Mirrors*
Wrenches	*Tubing Cutters*
Chisels	*Soldering Equipment*
Punches	*Feeler Gauges*
Files	*Micrometers*
Hacksaws	*Dial Indicators*
Vises	*Spring Testers*
Clamps	*Pressure Gauges*
Twist Drills	*Speed-Measuring Tools*
Screw Extractors	

SCREWDRIVERS

Most screwdrivers come in five basic designs:

- **Common**
- **Cross-recessed head**
- **Clutch-head**
- **Offset**
- **Starting**

Each one allows you to produce a twisting motion to tighten or loosen screws — but for different jobs.

COMMON SCREWDRIVER

X 2260

Fig. 2 — Common Screwdriver

Never use a screwdriver as a cold chisel, a punch, or a prying bar. If you must tap on the screwdriver, use one made for tapping.

Don't twist the shank of a standard screwdriver with a pliers or wrench. If necessary, use a heavy-duty screwdriver with a square shank.

Never use a screwdriver to check an electrical circuit where the amperage is high.

X 2261

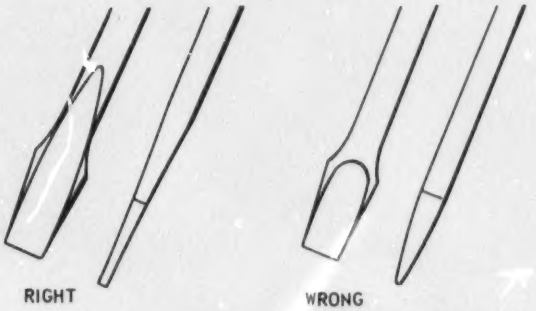
Fig. 3 — Be Sure The Screwdriver Fits The Screw Slot

Don't hold work in the hand while using a screwdriver — the point may slip and hurt you. A good rule is never to get any part of your body in front of the screwdriver bit.

Be sure the screwdriver bit fills the slot in the screw head (Fig. 3). Two small a bit will twist and "chew up" the screw.

Always hold the screwdriver shank vertical to the screw head as you twist it.

If the screwdriver bit becomes rounded or broken, it can be reground as follows:



X 2262

Fig. 4 — Grinding The Screwdriver Blade

1. Grind the tip until it is straight and at right angles to the shank (Fig. 4). The sides should have very little taper and should never come to a sharp point at the tip.

2. **IMPORTANT: Never hold the screwdriver against the grinding wheel for a long time.** Dip the bit in water to keep it cool. This will prevent loss of tempering and softening of the bit.

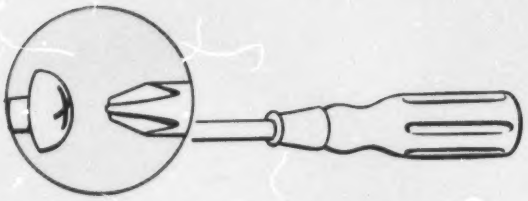
3. If the bit is correctly ground, it will stay down in the screw slot regardless of the twisting force. If ground with too much taper, the bit will rise out of the slot as it is turned.

NOTE: Only the end of the screwdriver bit is hardened, so there is a limit to how many times it can be successfully reground.

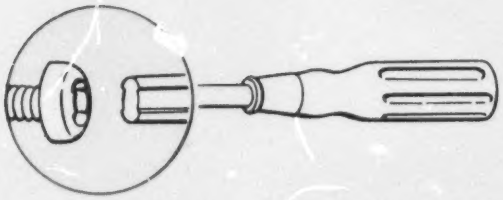
CROSS-RECESSED HEAD SCREWDRIVER

This screwdriver (Fig. 5) has a cross-shaped, pointed tip. It will not slip sideways out of the cross slots of a cross-recessed head screw, but more force must be exerted in keeping it in the slots.

If the bit gets broken, it is not practical to repair it.



CROSS-RECESSED HEAD SCREW DRIVER



CLUTCH-HEAD SCREW DRIVER

X 2263

Fig. 5 — Phillips-Head and Clutch-Head Screwdrivers

CLUTCH-HEAD SCREWDRIVER

This screwdriver (Fig. 5) is used with screws for sheet metal and trim where a neat appearance is vital. The tip of the screwdriver is very strong and stays in the screw opening with only moderate pressure.

OFFSET SCREWDRIVER

X 2264

Fig. 6 — Offset Screwdriver

Offset screwdrivers (Fig. 6) are used where space is limited and the screw is hard to reach. Bits are normally at right angles to each other, allowing the screw to be turned a quarter turn at a time by using opposite ends alternately.

Use the offset screwdriver cautiously as the bit has a tendency to jump out of the slot and damage the screw head.

STARTING SCREWDRIVER

Starting screwdrivers (Fig. 7) are used for removing and installing screws in places difficult to reach with the hand. Once a screw is started, a common screwdriver can often be used to finish the job.

Other starting screwdrivers have twisting centers or are magnetized to hold the screws.

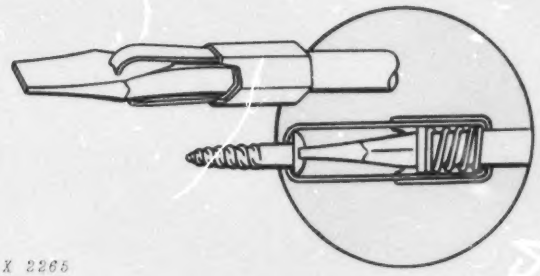


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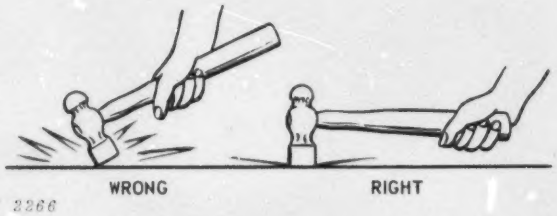
Fig. 7 — Starting Screwdriver (Shown Holding Screw)

HAMMERS

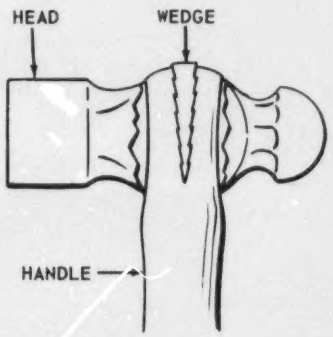
There is a right way and a wrong way to use a hammer, regardless of the type.



X 2266

Fig. 8 — Correct Use Of A Hammer

Always grip the hammer close to the end of the handle to increase leverage for a harder blow (Fig. 8). Whenever possible, strike the object squarely with the full face of the head to prevent damage to the hammer face and to the object.



X 2267

Fig. 9 — Correct Installation of Hammer Head On Handle

The handle of a steel hammer extends through the head and is held tightly in the head by a wedge (Fig. 9). If the wedge starts to come out, drive it in again to tighten the handle. If the wedge is lost, replace it before using the hammer. **Never work with a hammer having a loose head.**

The hammer handle should never be used for prying or pounding.

Never use a steel hammer on a machined surface.

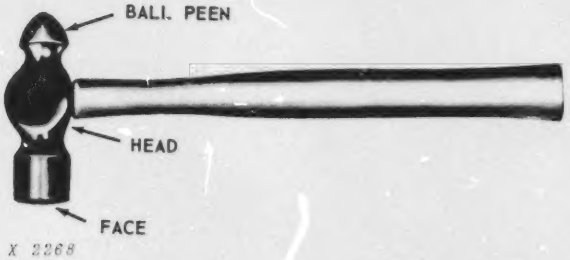


Fig. 10 — Ball Peen Hammer

Ball peen hammers (Fig. 10) are most commonly used by shop servicemen. The flat face is for hammering and the ball part is for rounding off rivets and similar jobs.

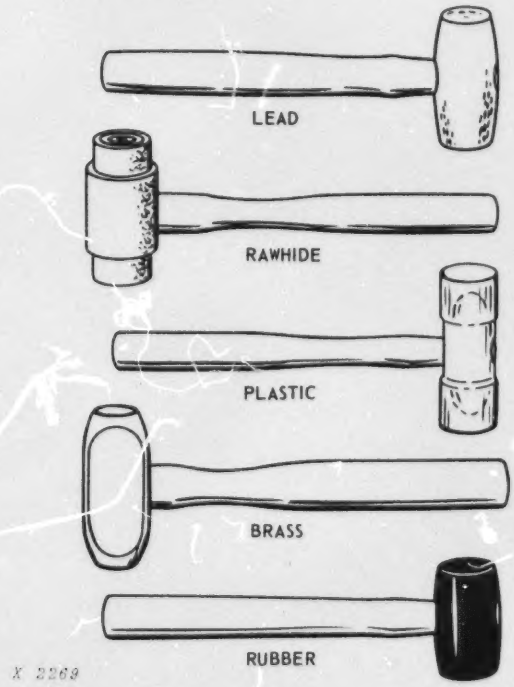


Fig. 11 — Soft Hammers

Soft hammers (Fig. 11) are used in place of steel hammers to protect machined surfaces or fragile parts. These hammers are commonly made of lead, rawhide, plastic, brass, or rubber.

PLIERS

COMBINATION PLIERS

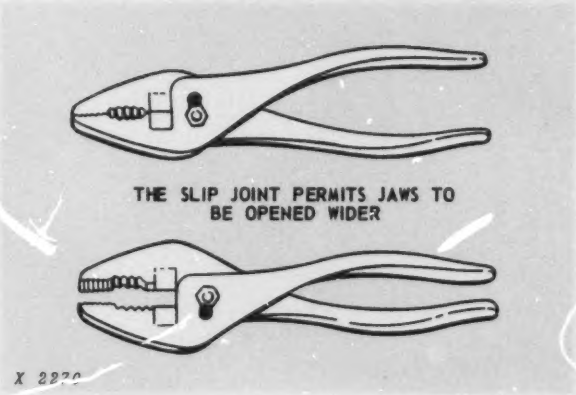


Fig. 12 — Combination Pliers

Combination pliers (Fig. 12) are often misused. They are made for *holding* work — not for tightening or loosening nuts.

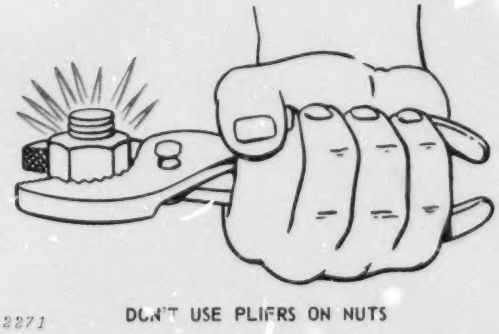


Fig. 13 — Wrong Use Of Pliers

A slip joint permits the jaws to be opened wider. For extra-wide objects, rib-joint pliers are used.

Avoid using pliers on hardened surfaces as this dulls the teeth of the pliers and they lose their grip.

DIAGONAL CUTTER PLIERS

Diagonal cutter pliers (Fig. 14) are ideal for pulling cotter pins, especially from slotted nuts. They may also be used for spreading the ends of cotter pins. *Never use diagonal pliers for cutting large-gauge wire.*

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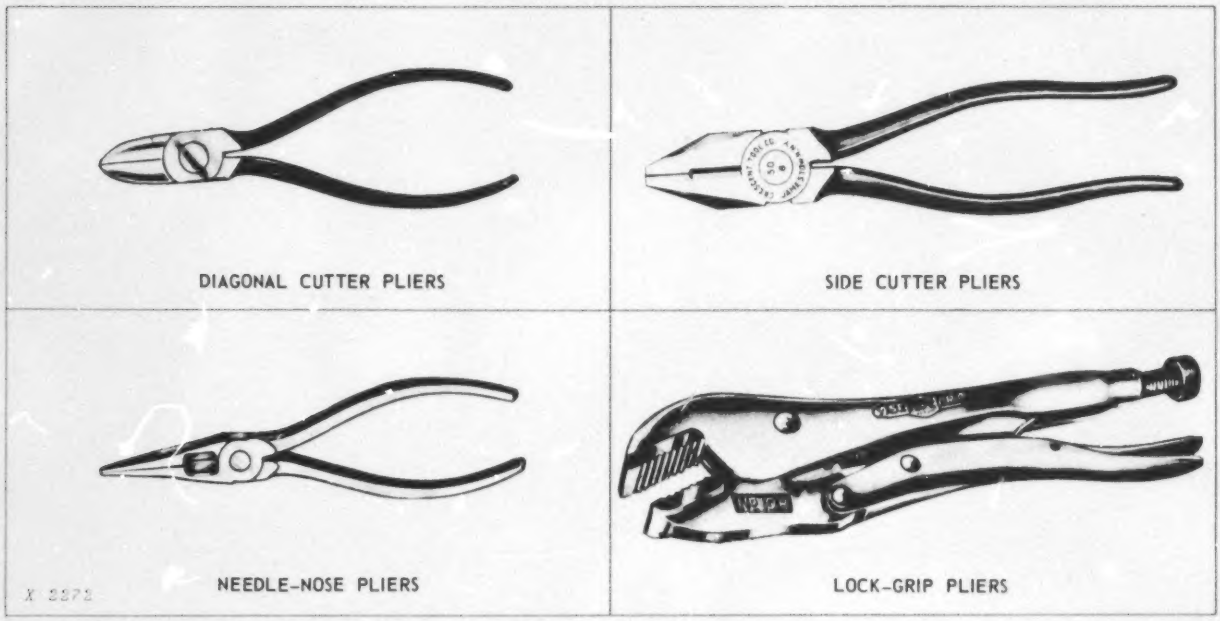

Fig. 14 — Pliers

SIDE CUTTER PLIERS

Side cutter pliers (Fig. 14) are for the serviceman who cuts a lot of large-gauge wire.

NEEDLE-NOSE PLIERS

Needle-nose pliers are used primarily for handling small objects and for reaching into restricted areas. Never force them beyond their gripping capacity.

LOCK-GRIP PLIERS

Lock-grip pliers (Fig. 14) are specially designed to clamp and hold a round object. One jaw is adjustable to fit different sizes of nuts, bolt heads, pipes, or rods.

Never use these pliers on material where marring the finish is a problem.

SNAP RING PLIERS

Snap ring pliers (Fig. 15) are used to spread snap rings just the right amount as they are removed or installed.

This is a handy tool and also helps prevent overexpanding of snap rings.

Fig. 15 — Use Of Snap Ring Pliers

OTHER TYPES OF PLIERS

Special types of pliers are also available for certain jobs: Battery (terminal nut) pliers, water pump nut pliers, ignition pliers, hose clamp pliers, brake spring pliers, retaining ring pliers, groove-grip snap ring pliers, horseshoe lock ring pliers, and slip-joint (channel) pliers.

CARE OF PLIERS

Keep pliers clean and occasionally put a drop of oil on the joint pin. This will prevent rusting, the enemy of all tools.

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WRENCHES

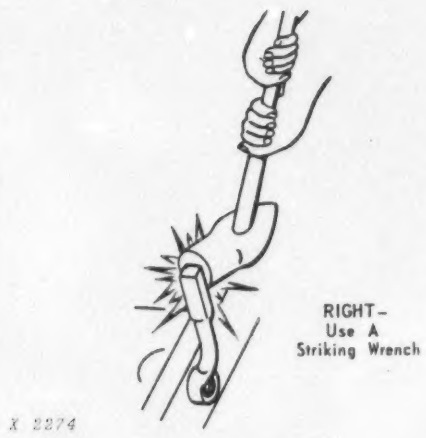

Fig. 16 — Never Hammer On A Standard Wrench

Never hammer on a standard wrench. Use a heavy-duty striking wrench designed for use with a hammer (Fig. 16).

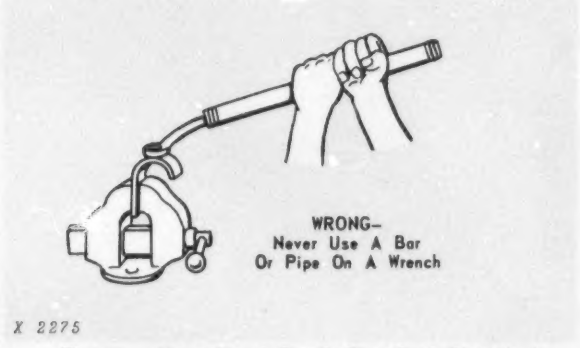

Fig. 17 — Never Use A Bar Or Pipe On A Wrench

Never use a bar or pipe to increase leverage on a wrench (Fig. 17). The only exception is when the work is hard to reach and you must use an extension, as with a socket wrench (Fig. 26).

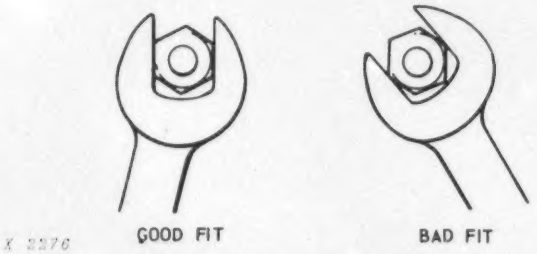

Fig. 18 — Correct Fit Of Wrench On Nut Is Important

Be sure the wrench fits the nut or bolt head (Fig. 18).

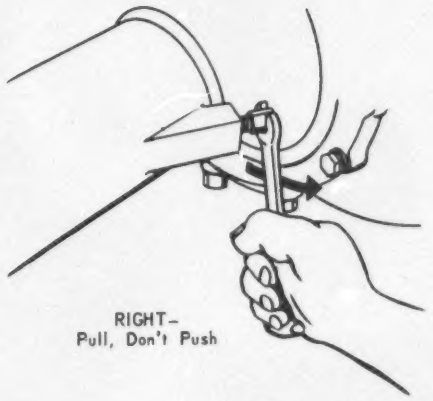

Fig. 19 — Always Pull On A Wrench — Don't Push

Always PULL on a wrench — don't PUSH. Save your knuckles (Fig. 19) If you must push, use the base of your palm and keep your hand open.

OPEN-END WRENCHES

Open-end wrenches have an opening at each end. The openings designate the size of wrench in inches (or millimeters) and are often combined, as 5/16 by 3/8 (metric wrenches — 16 mm by 18 mm). These figures refer to the distance across the flats of the nut or bolt and not the bolt diameter.

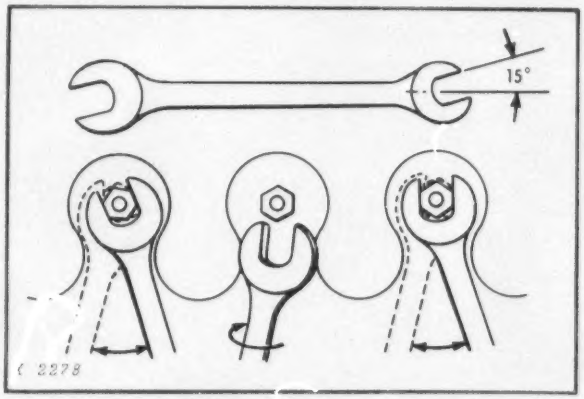

Fig. 20 — Loosen Nuts In Crowded Places By "Flopping" The Wrench

The head and opening of an open-end wrench is normally at an angle of 15 or 22-1/2 degrees to the body (Fig. 20).

The offset allows you more swing space in crowded places by "flopping" the wrench as shown.

ADJUSTABLE OPEN-END WRENCHES

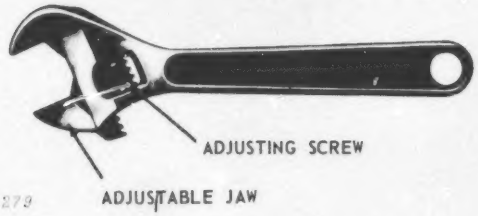

Fig. 21 — Adjustable Open-End Wrench

The adjustable open-end wrench (Fig. 21) has a sliding jaw moved by an adjusting screw. This wrench is not meant to take the place of an open-end wrench, except when an odd-sized nut or bolt is encountered. This does help to cut down the number of open-end wrenches you need to carry.

Adjustable wrenches aren't intended for hard service — treat them gently.

Fig. 22 — Correct Use Of Adjustable Open-End Wrench (Tightening Shown)

Fig. 23 — Tighten The Adjustable Wrench On The Nut

Remember these three points:

1. Always place the adjustable wrench on the nut so that the pulling force is applied to the stationary jaw side of the wrench (Fig. 22). This side can withstand much greater force.

2. After placing the wrench on the nut, tighten the adjusting screw so that the wrench fits the nut snugly (Fig. 23). Otherwise the nuts will be rounded off.

3. Keep the wrench clean. Wash it occasionally in cleaning solvent and apply a light oil to the adjusting screw and slide.

BOX WRENCHES

Box wrenches completely surround the nut to avoid slipping and are handy for working in close quarters.

In place of the hexagonal or six-sided opening, most box wrenches have 12 notches arranged in a circle and are called 12-point wrenches. A 12-point wrench can be used to continuously loosen or tighten a nut with a minimum swing of the handle of only 15 degrees, compared to a 30 or 60 degree swing of the open-end wrench. Larger box wrenches are also available in six-point styles.

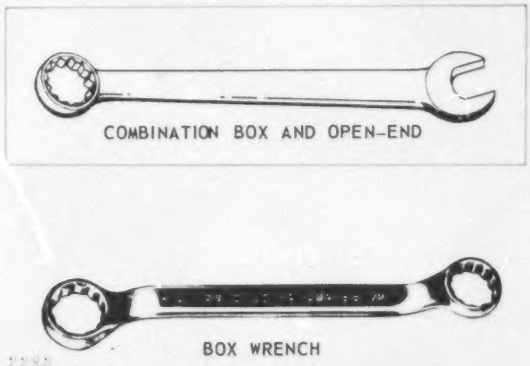

Fig. 24 — Box Wrenches

Some box wrenches are made with an offset at one or both ends (Fig. 24). This provides clearance for your hands and saves knuckles.

Combination box and open-end wrenches (Fig. 24) can speed up nut-and-bolt installations. The box end is used to break loose or snug down the nut, while the open-end is used for greater speed the rest of the time.

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TUBING WRENCHES

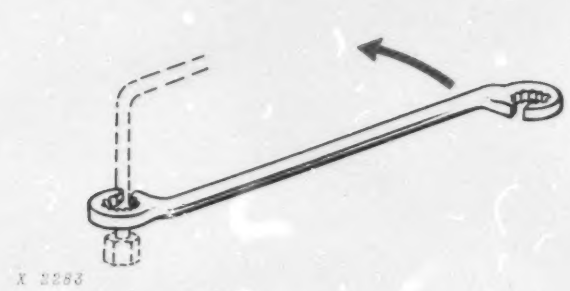

Fig. 25 — Tubing Wrench

A tubing wrench (Fig. 25) is similar to a box wrench but has a cut-out large enough to slip over hydraulic tubing. When using the wrench, pull only in the direction of the arrow in Fig. 25 to avoid spreading the wrench opening.

SOCKET WRENCHES

Socket wrenches have done the most to make service work faster and easier. Fig. 26 shows a modern twelve-point socket wrench, a sliding T-handle, a speed handle, a universal joint, and a ratchet handle. In addition, several extensions and L-handles are available. Combined in various ways, these socket sets can do many nut-and-bolt jobs. Larger sockets are also available in six-point styles.

To use the socket wrench with a ratchet, you select the size of socket that fits the nut, engage it on the ratchet handle and place the socket on the nut.

Inside the head of the ratchet handle is a pawl or dog which engages or fits into one or more of the ratchet teeth. Pulling on the handle in one direction, the dog holds in the ratchet teeth and turns the socket. Moving the handle in the other direction, the dog ratchets over the teeth, permitting the handle to be backed up without moving the socket (see insert at left in Fig. 26). That's why the ratchet handle can be worked so rapidly — the socket does not have to be raised off the nut to get another "bite." The handle ratchets in one direction when tightening a nut and in the other direction when loosening a nut.

A means usually is provided on the handle for changing the direction of ratcheting (see insert at right in Fig. 26). On some makes there is a little lever which is flipped to the right to make the head ratchet when the handle is moved in a counterclockwise direction. This is the way you want it to work when tightening a nut. When unscrewing a nut the lever is flipped to the left and the handle then ratchets in a clockwise direction.

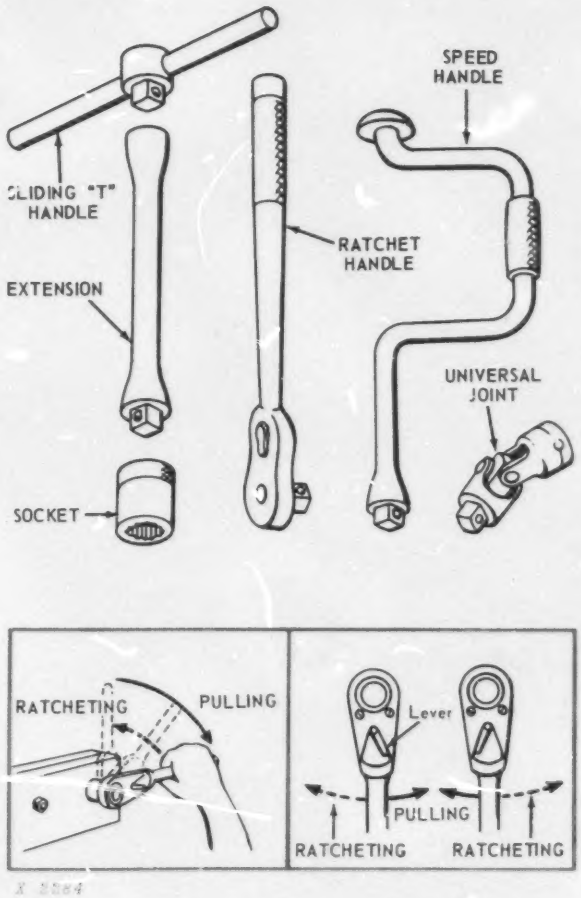

Fig. 26 — Socket Wrenches And Handles

The reason that a modern socket wrench set is so adaptable for repair work is that in addition to the set of sockets and the ratchet handle, it contains numerous other accessories.

The hinged offset handle is very convenient. To loosen a tight nut the handle can be swung so as to be at a right angle to the socket and thus provide the greatest possible leverage. Then, after the nut is loosened to the point where it turns easily, the handle can be hinged into the vertical position and twisted by the fingers to completely remove the nut from the bolt or the stud.

Another part of the socket set is the sliding offset handle. The head can be positioned at the end or at the center of the handle. The sliding offset and an extension bar can be made up as a "T" handle.

Speed handles sometimes called "speeders" or "spinners" are convenient for many jobs such as removing or tightening oil pan screws. The speed

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handle is worked like a brace which the woodworker uses with a bit to bore holes. A speed wrench will help you get cylinder head nuts off in a hurry after they are first broken loose with the sliding offset or the ratchet handle.

A universal joint frequently comes in very handy when working on nuts in those places where a straight wrench cannot be used. The universal joint enables you to work the wrench handle at an angle with the socket. Often this is a big help when working close places.

Large socket wrench sets also contain extra deep sockets for use on spark plugs and on nuts which are a long way down on the bolts, such as on U-bolts.

Another accessory for the socket wrench set is a handle which measures the amount of pull you put on the wrench. This is called a "torque wrench." We will cover torque wrenches later in this chapter.

Keep all parts of the socket set free of dirt and grit. Wash them occasionally in cleaning solvent and apply a light oil to all universal joints and ratchets.

SET SCREW WRENCHES

Fig. 27 — Set Screw Wrench

These wrenches (Fig. 27) are for headless set screws and other countersunk hardware. All of them are L-shaped bars of tool steel, usually hexagonal.

SPANNER WRENCHES

Spanner wrenches (Fig. 28) are usually special tools supplied with a machine. There are a number of types: The hook type (shown), U-shaped hook type, end spanner, pin spanner, and face pin spanner.

WHICH WRENCH TO USE?

Now that we have talked about all of the ordinary wrenches used by servicemen, you may wonder how you are to find out which is the best type of wrench to use for the particular work you are doing. Should it be an open-end wrench, an adjustable wrench, a socket wrench, a box wrench or a combination box and open-end wrench? This is something that is best learned by actual experience, but there are a few simple rules which will be helpful.

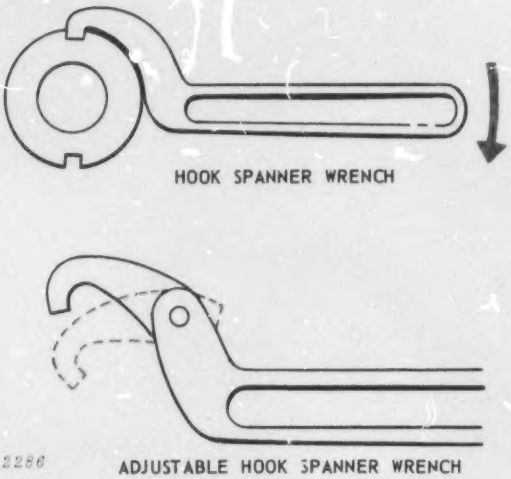

Fig. 28 — Spanner Wrenches

The type of job to be done, and the location and number of nuts or cap screws are the things to consider when selecting the wrench.

Usually, if there are a number of nuts to be taken off or put on, the socket wrench set is what you should use. In removing the cylinder head from an engine, for example, you would first break the nuts loose by using a socket on a hinged offset handle with the handle bent over at an angle of practically 90 degrees to provide the necessary leverage. Then after the nuts were broken loose, the hinged handle would be held in the vertical position and twisted with the fingers to run them off.

If the engine is installed in a machine and there is plenty of room to operate a speed handle, then after breaking the nuts loose with the offset handle, transfer the socket to a speed handle and use this combination to spin the nuts off.

In replacing and tightening the nuts, the wrenches would be used in the reverse order.

For such jobs as removing and installing engine oil pans, timing gear covers, and transmission case covers, the right size of socket on a speed handle would be the best wrench to use. It can be used to loosen or tighten these cap screws because no great amount of force is required.

There are many nuts, particularly those on some intake and exhaust manifolds, where box, socket, or combination box socket and open-end wrenches can be used to good advantage.

For the nuts on fuel and oil lines, hydraulic brake lines, and clutch and transmission control rods, open-end wrenches or tubing wrenches are the only wrenches that can be used.

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With a little actual experience in the shop, and after using each type of wrench in the tool kit a few times, you will find that with a little THINKING it is not at all difficult to select the type best suited for the job and to pick the right-size wrench. A good serviceman is the man who can use his head as well as his hands — who can coordinate his brain and muscles.

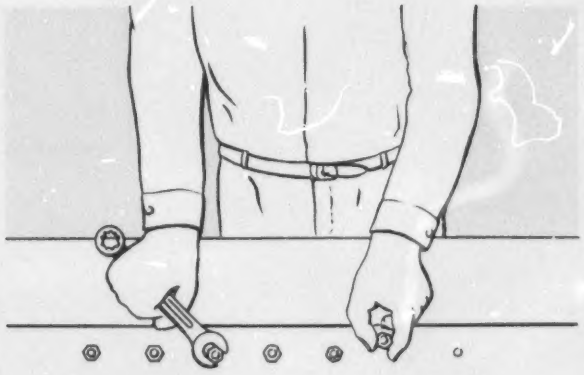

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Fig. 29 — Using Both Hands To Get The Job Done In Half The Time

For instance, in replacing cylinder head nuts you will find you can get the job done in about half the time if you use both hands simultaneously instead of just one (Fig. 29). It is something like learning to use a typewriter — the beginner starts with two fingers but the experienced typist uses all ten. It is just a matter of practice.

TORQUE WRENCHES

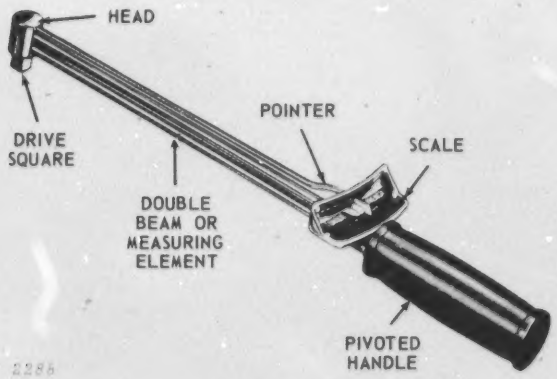

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Fig. 30 — Torque Wrench

A torque wrench (Fig. 30) measures resistance to turning — called **torque.**

Torque and tension are not the same thing. **Torque is twist,** measured in *foot-pounds (Newton-meters).* **Tension is a straight pull,** measured in *pounds (Newtons).* Wrenches designed to measure the tightness of a nut are **torque** wrenches, not tension wrenches.

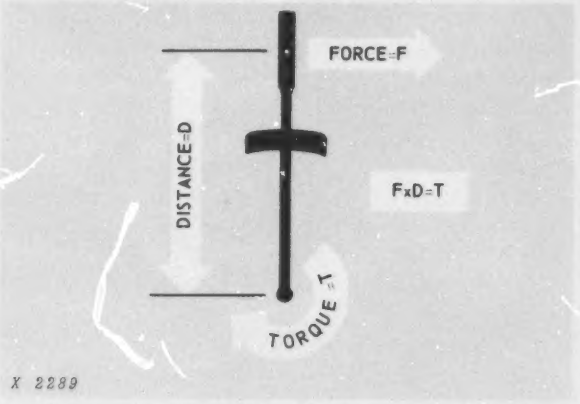

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Fig. 31 — Formula For Torque

TORQUE is based on the fundamental law of the lever — FORCE X DISTANCE = TORQUE. This is shown in Fig. 31.

Lever length is the distance from the center of the drive square (Fig. 30) to the axis of the handle pivot where the force is concentrated.

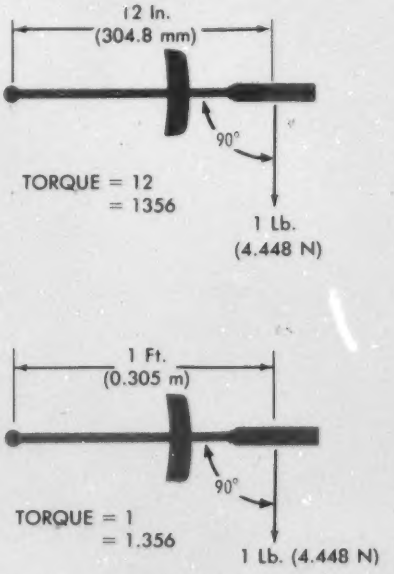

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Fig. 32 — Units For Measuring Torque

If the lever length is measured in inches (millimeters) and the force in pounds (Newtons), then the torque developed is measured in **inch-pounds (Newton-millimeters).** If the lever length is measured in feet (is more than 12 inches) (meters), then the result is termed **foot-pounds (Newton-meters)** (Fig. 32).

Foot-pounds multiplied by 12 = Inch-pounds.
(Newton-meters multiplied by 1000 = Newton-millimeters)

Inch-pounds divided by 12 = Foot-pounds.
(Newton-millimeters divided by 1000 = Newton-meters)

Most torque wrenches have a signaling device which can be preset for the torque desired. When you reach that torque on the wrench, you are signaled by the wrench.

Formula For Torque Of Adapter Or Extension

Adapters and attachments can be used with torque wrenches to aid in reaching inaccessible places.

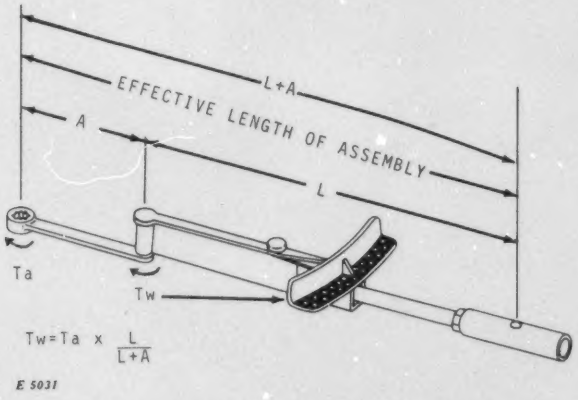

Fig. 33 — Calculating Torque With An Adapter

When an adapter is used with the torque wrench, the total effective length of the assembly is the sum of the lever length (L) plus the adapter length (A) as shown in Fig. 33. To get the actual torque reading, use the following formula:

Ta = torque at end of adapter
Tw = torque wrench reading
L = lever length of torque wrench
A = length of adapter

The formula is:

$$Ta = Tw \times \frac{L + A}{L}$$

Selecting A Torque Wrench

Selecting the proper size and range of torque wrench is important in getting accurate results. A good rule of thumb is to select a torque wrench having enough capacity so that your working range is within the middle two quarters of the scale.

For example, if you choose a 600 foot-pounds capacity torque wrench, any job within 150 to 450 foot-pounds is the best working range. Under normal conditions, this will give you the most accuracy.

Using A Torque Wrench

Torque wrenches can be pulled or pushed. Apply force steadily.

If a seizure occurs while tightening, back off the nut and retighten it with a steady sweep of the handle. Take the torque reading while the wrench is moving.

When tightening a nut or bolt with damaged or blocked threads, note what torque is required to move through the damaged area. Then add this extra torque to the recommended reading.

Handle torque wrenches very carefully. If the wrench is dropped, check it for accuracy before using it again.

Checking Torque Wrench For Accuracy

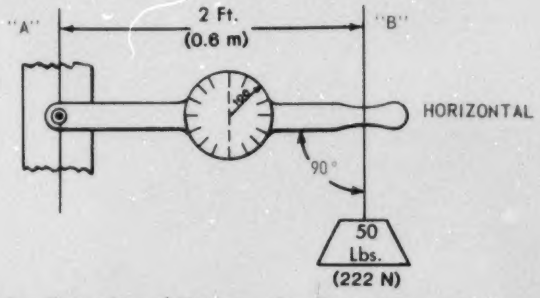

Fig. 34 — Checking Torque Wrench For Accuracy

To check the accuracy of a rigid torque wrench, do the following:

1. Hang the torque wrench on a fixed nut as shown in Fig. 34.

2. Set the indicator to "0". (This will compensate for the weight of the wrench.)

3. Hang a known weight from the wrench handle at any known distance from the center of the nut as shown.

4. Weight in pounds multiplied by the distance from A to B in feet will give you the ft.-lbs. of torque. This figure should agree with the indicator reading.

Example shown: **50 lbs. x 2 ft. = 100 ft.-lbs.**
(22.7 kg x 9.81 = 222 N;
222 N x 0.6 m = 133 N·m)
Note: 9.81 is a factor for gravitational pull.

Remember that any weight or distance can be substituted in the formula, Weight x Distance = Torque.

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NOTE: To check the accuracy of flexible torque wrenches, hang the weight from the pivot point of the handle. Weight x Distance will then give you the Torque.

Always check wrenches within the range where they are normally used.

Why Proper Torque Is All-Important

Bolt torque is based on this concept: For a bolt to stay tightened, it must be tightened enough so that the load *in the bolt* is greater than the loads which the bolt must *absorb* during operation.

Overtightened bolts are "stretched" until their threads are damaged or assembly parts are warped or misaligned.

Undertightened bolts allow a "shearing" force to develop between the mating parts as they try to move. If the parts impose a greater stress than the stress or load in the bolt, they will eventually fatigue and break the bolt or work it loose.

Up to 90 percent of applied torque is used for overcoming friction, but the percent varies with different types of bolts and nuts. Other variables include the material in the parts to be held together, location of the assembly, forces exerted on it, and lubrication of the bolt threads. In short, every torquing job varies, and that is why a specific torque is given in the machine Technical Manual for each location.

A general guide for torquing various types of bolts and nuts is given in the chart which follows. For torques on other fasteners, refer to the complete torque guide on pages 34 and 35 of this manual.

BOLT TORQUE CHART

Recommended Torque In Ft.-Lbs. (Coarse And Fine Threads)

Bolt Diameter	*LOW STRENGTH "B" Grade (Plain Head)*	*HIGH STRENGTH "D" Grade (3-Dash Head)*	*EXTRA HIGH STRENGTH "Alloy" Grade (6-Dash Head)*
1/4	Not used	10	14
5/16	Not used	20	30
3/8	Not used	35	50
7/16	35	55	80
1/2	55	85	120
9/16	75	130	175
5/8	105	170	240
3/4	185	300	425
7/8	160*	445	685
1	250*	670	1030
1-1/8	330*	910	1460
1-1/4	480*	1250	2060

**"B" Grade bolts larger than 3/4-inch are sometimes formed hot rather than cold, which accounts for the lower recommended torque.*

METRIC BOLT TORQUE CHART

Recommended Torque In N·m

Bolt Diameter	*Property Class 4.8* (4.8)	*Property Class 8.8* (8.8)	*Property Class 10.9* (10.9)
M5	3	7	9
M6	6	12	16
M8	15	30	40
M10	25	55	75
M12	50	100	135
M14	80	160	215
M16	125	245	335
M20	240	460	650
M24	410	825	1125
M30	820	1640	2240
M36	1435	2870	3910

Allow a tolerance of plus or minus 10% on all torques.

NOTE: Multiply readings by 12 for inch-pound values (by 1000 for N·mm readings).

The property class of the bolt is marked on the head using a pattern of dashes or numbers (see charts). Always replace with bolts of the same property class. Whenever in doubt, use a *higher*-grade bolt as a replacement.

CHISELS

Cold chisels are used for cutting metal in jobs such as breaking rivets and splitting nuts.

CORRECT USAGE

Ordinarily the chisel should be held between the thumb and first finger about an inch from the head of the chisel. Hold it with a steady but rather loose grip to lessen the blow on the hand in case of a miss.

When chipping with a chisel, **wear safety glasses.**

A chisel will cut any metal softer than itself. Always use a chisel that is big enough for the job and a hammer that is heavy enough for size of chisel; the larger the chisel, the heavier the hammer.

Fig. 35 — Flat Cold Chisel

FLAT COLD CHISEL

The flat cold chisel (Fig. 35) is the one most used by the serviceman. The cutting edge is slightly convex (curved outward) as shown in Fig. 36. This causes the center portion to receive the greatest shock, thus protecting the weaker corners. Cutting edge angle should be 60 to 70 degrees for general use.

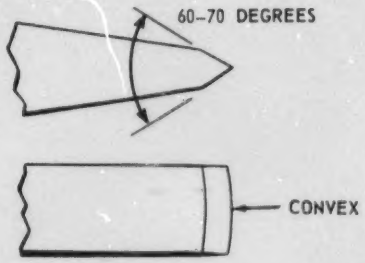

Fig. 36 — Correct Shape Of Flat Cold Chisel Edg

SPECIAL COLD CHISELS

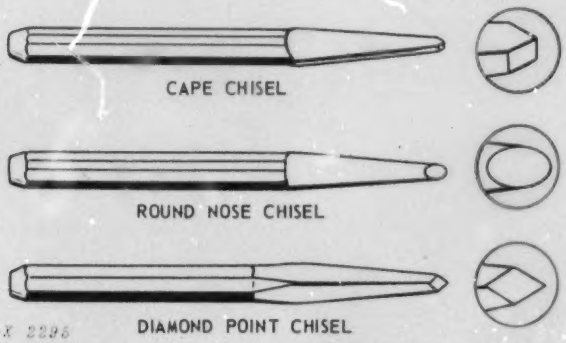

Fig. 37 — Special Chisels

Cape chisels (Fig. 37) are used for cutting keyways, narrow grooves, and square corners.

Round nose chisels are used for cutting semi-circular grooves and chipping inside corners which have a fillet or radius.

Diamond point chisels are used for cutting V-grooves and square corners.

PROPER CARE OF CHISELS

CAUTION: When grinding a chisel, never hold it against the grinding wheel for any great length of time. Dip it frequently in water or coolant to keep it cool. Unless this is done, heat caused by friction with the grinding wheel will draw the temper and cause the cutting edge to become soft and almost useless.

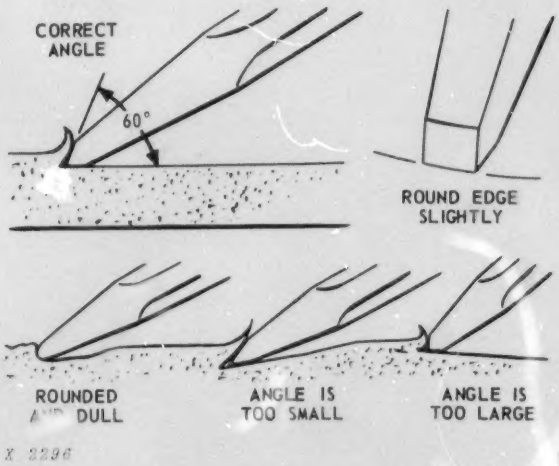

Fig. 38 — Results Of Correct and Incorrect Chisel Grinding

Fig. 38 shows the results of correct and incorrect chisel grinding.

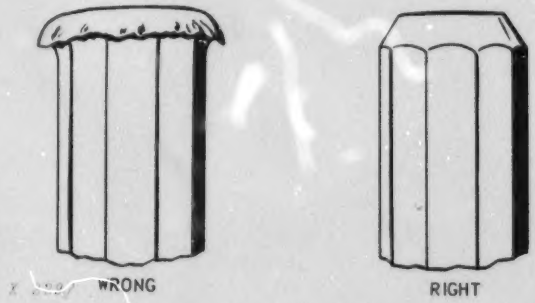

Fig. 39 — Chisel Heads

The head of a chisel will spread or mushroom out after being used a great deal as shown at left in Fig. 39. This spreading is rough, and will injure the inside of the hand [illegible] chisel should slip. Also, pieces may break [illegible] the overhang with enough force to cause injury. For safety, keep the chisel head down as shown at right in Fig. 39.

PUNCHES

CORRECT USAGE

When using a punch, hold it with a steady, but rather loose grip to lessen the blow on the hand in case of a miss. Always use a hammer proportionately large enough for the punch.

The head of a punch will, in time, spread or "mushroom," and should be ground down to prevent injury.

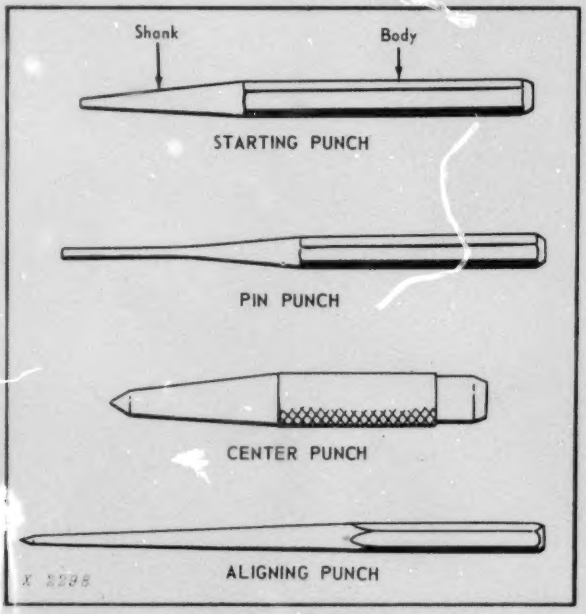

Fig. 40 — Punches

STARTING PUNCHES

A starting punch has a long gentle taper which extends from the tip to the body of the punch. This type of punch is used to knock out rivets and to start driving out straight or tapered pins.

PIN PUNCH

A pin or drift punch (Fig. 40) is used for driving out pins after the starting punch can no longer be used. *CAUTION: Never use a pin punch to start a pin.* Since it has a slim shank, a hard blow may cause it to break or bend.

CENTER PUNCH

A center punch (Fig. 40) is used to mark the location of a hole that is to be drilled and so eliminate drill "wandering."

Frequently, the serviceman will use a center punch for marking the relationship between mating parts.

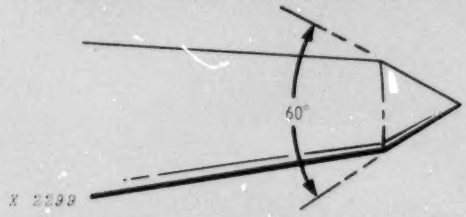

Fig. 41 — Correct Angle For Point Of Center Punch

The point on a center punch is accurately ground and is concentric with the punch body. Included angle is usually 60 degrees as shown in Fig. 41. Do not use a center punch on metal that is so hard it may dull the point.

ALIGNING PUNCH

An aligning punch (Fig. 40) is useful in shifting parts so corresponding holes "line up." *CAUTION: An aligning punch should never be used as a center punch.*

FILES

Files (Fig. 42) are made in numerous sizes and shapes, each one having a specific use. They are further designated by the coarseness or fineness of teeth, shape of teeth, and whether they have single- or double-cut teeth.

Fig. 42 shows what the various parts of a file are called. The size is figured from the heel to end of tip.

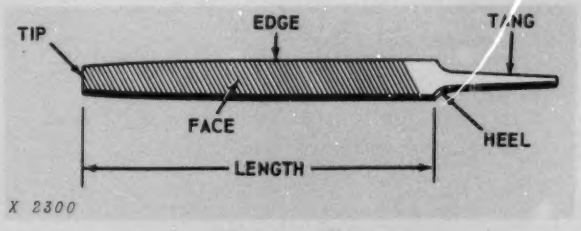

Fig. 42 — File

There are many kinds of files, but here we will cover only those a serviceman will normally use.

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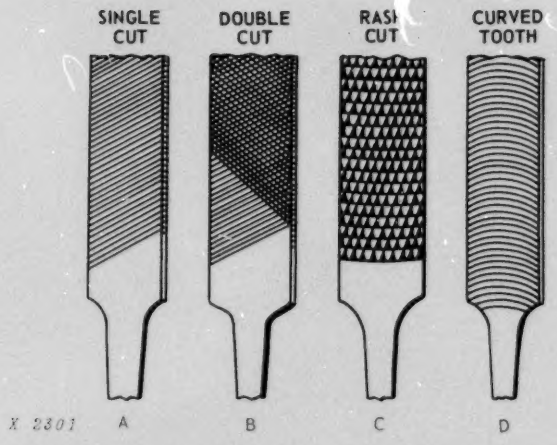

Fig. 43 — Four Types Of File Teeth

Shown in Fig. 43 are four representative files generally used in shops.

"A" shows a **mill file,** which received its name by having been used to sharpen saws. Mill files are always single-cut, meaning only one row of teeth appear on the blade.

"B" illustrates a **machinist's file,** which has double-cut teeth.

"C" is a **rasp cut file** on which all teeth have been individually cut and disconnected from each other for independent teeth in cutting.

"D" is a **curved tooth file** which has a single row of teeth cut on the blade in a curve to aid in self-cleaning.

Mill and machinist's files are further classified with reference to coarseness of teeth into Bastard, Second-cut, and Smooth-cut.

Mill files are generally used for tool sharpening. Machinist's files are used for filing and finishing machine parts. Rasp files are used for cutting wood and very soft metals. The curved tooth file is used on aluminum and steel sheets.

CORRECT USE OF FILES

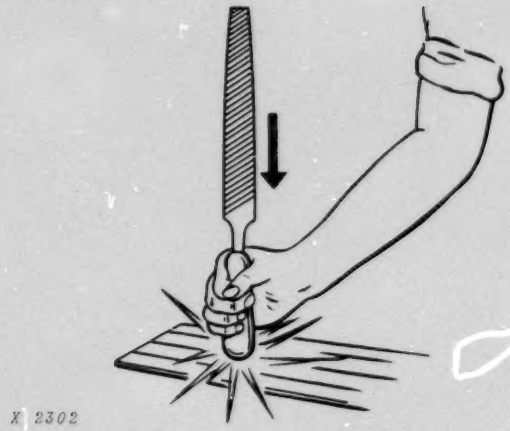

Fig. 44 — Tightening File Handle

Before attempting to use any file, equip it with a tight-fitting handle similar to that shown in Fig. 44. This eliminates the danger of injuring your hand.

Normally *PUSH the file across the work, cutting only on the forward stroke.* To prevent damage to teeth, raise the file from the work on the return stroke.

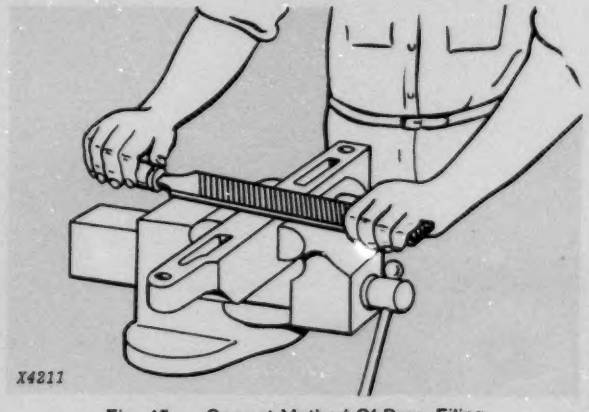

Fig. 45 — Correct Method Of Draw-Filing

When it becomes necessary to finish a flat-surface, for example a gasket surface, it should be draw-filed. This is done by using a machinist's file and drawing the file crosswise over the work with a light pressure (Fig. 45). Holding the file in this manner allows it to cut when moving in both directions.

When using a file, *apply only enough pressure to keep the file cutting.*

Never hammer on a file, or use it for prying. Do not use the file after the teeth have become clogged until it has been properly cleaned. Learn to tap the file at the end of the stroke to clear the teeth of chips.

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PROPER CARE OF FILES

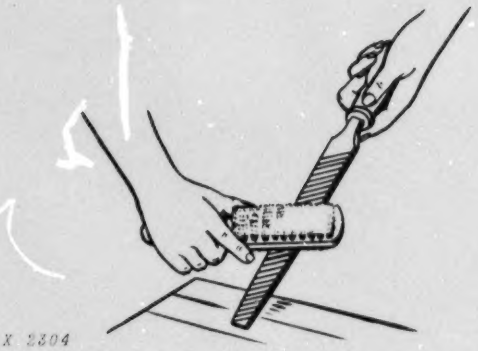


Fig. 46 — File Card

Clean a file by using a file card (Fig. 46). This is a brush with short, stiff wire bristles. If chips are left after using the file card, they should be lifted out with a pointed or flattened cleaning wire called a "scorer" which is included as a part of most file cards.

To keep files sharp, see that their surfaces are protected when not in use. Do not throw files around on the bench or into a drawer. Keep files away from water to prevent rusting and keep them from getting oily, as this prevents fast, clean cutting.

HACKSAWS

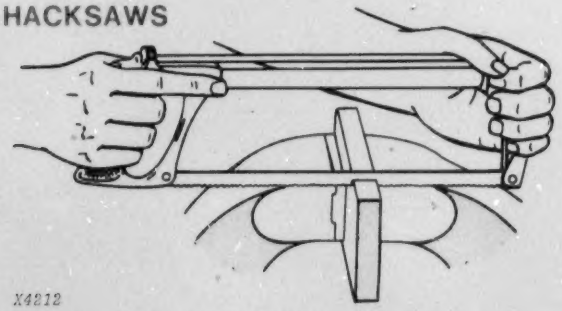


Fig. 47 — Correct Way To Use A Hacksaw

Hacksaw frames are designed to take blades of various lengths. The blade can be positioned at various angles along its axis.

CORRECT USE OF HACKSAW

When placing blade in frame, be sure the frame is correctly adjusted for length of blade with sufficient adjustment remaining to permit the blade to be *tightly stretched.* A properly stretched blade will vibrate with a clear humming sound when plucked.

Place blade on pins so teeth point AWAY from handle.

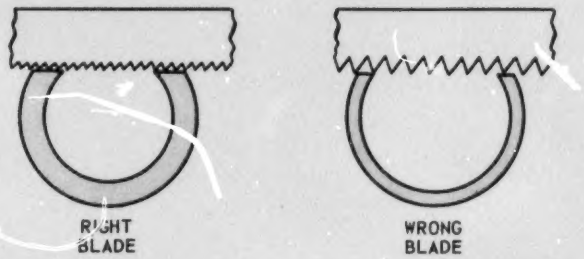


Fig. 48 — Selecting the Correct Hacksaw Blade

Always use a blade suitable for the thickness of the material to be sawed. Blades are made with 14, 18, 24 and 32 teeth per inch (5.5, 7, 9.5, and 12.5 teeth per cm).

The most simple method of selecting the proper blade is to remember that *two saw teeth should always be contacting the material when sawing.*

Fig. 48 shows the correct blade being used to saw thin material. The diagram at right shows how a blade with teeth too large will cause the work to fall between two teeth, making it almost impossible to saw and damaging the saw blade.

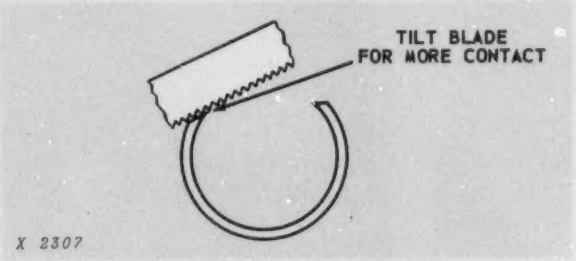


Fig. 49 — Sawing Thin Tubing

When cutting very thin material, such as tubing, shift the angle of the saw blade as cutting progresses to increase the area of contact between blade and material, allowing as many teeth as possible to contact the work at one time (see Fig. 49).

Use sufficient pressure on the forward or cutting stroke so that the teeth actually bite into metal. It is not necessary to lift blade from work on back stroke, but pressure should be relieved. Always use sufficient pressure to keep blade from getting pinched or jammed in the work as this often breaks teeth or blade.

Except when starting, use the full length of the blade on every stroke.

For efficient cutting of average metal, work the blade at 40 to 50 strokes a minute. Reduce this rate

FOS — 51 Litho in U.S.A.

for harder metals. There is a limit to the hardness of metal that can be sawed.

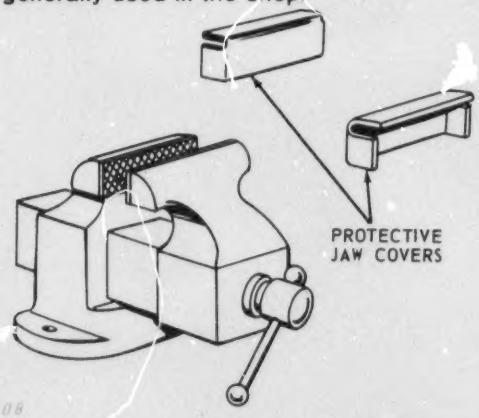
PROPER CARE OF HACKSAWS

Wipe the blade occasionally with an oily cloth to keep it from rusting. Also, keep the blade away from other tools to eliminate the possibility of teeth being broken or dulled.

Normally, metal hacksaw blades are never sharpened due to the fine teeth and the hardness of the metal. For these reasons, replace them when worn.

VISES

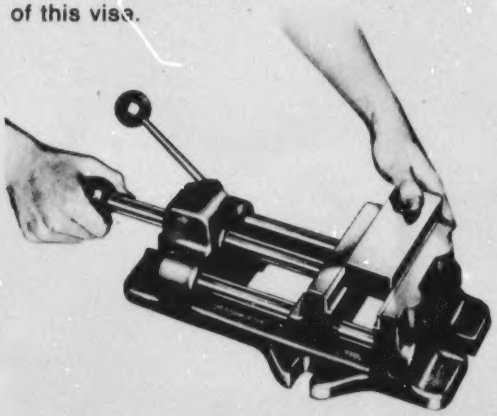
A vise is a heavy-duty holding tool. Several types are generally used in the shop.



X 2308

Fig. 50 — Machinist's Bench Vise

Fig. 50 shows the most commonly used machinist's **bench vise.** Also illustrated are jaw covers of soft metal used to hold machined parts to prevent marring the surfaces. A similar type is the **anvil vise.** Light hammering may be done on the stationary jaws of this vise.



X 2309

Fig. 51 — Drill Press Vise

Fig. 51 shows a **drill press vise,** which should always be used when drilling small parts. It is dangerous to attempt drilling small pieces when holding them with pliers or hands.

CORRECT USE OF VISES

Never use a hammer to tighten or loosen a vise, the weight of the body is sufficient.

Always use a vise big enough for the parts or type of work to be held.

When round parts must be held, soft metal or hard wood jaws can be used to prevent slipping or damage to parts. Whenever finished surfaces must be held, be sure to use soft metal jaw covers as shown in Fig. 50 to prevent marring the finish.

CLAMPS

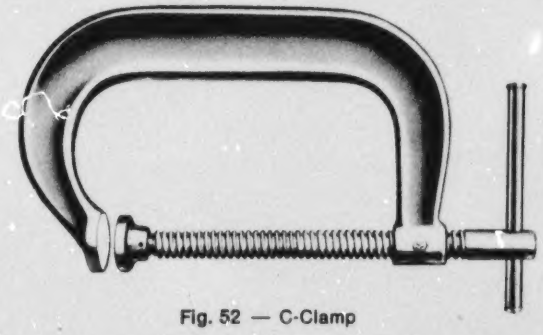


Fig. 52 — C-Clamp

C-clamps (Fig. 52) are more portable and versatile than vises, but do not hold the complete work stationary. However, they are handy for fastening materials together, as while welding.

TWIST DRILLS

Twist drills (Fig. 53) are made of either carbon tool steel or high-speed tool steel. Carbon steel will lose its temper if excessively heated and allowed to cool. High-speed steel drills can become "red hot", then cool, and still not lose their temper.

Fig. 53 shows the parts of a twist drill. Drills with three or four flutes are used only for enlarging drilled holes or drilling out cored holes. Two-fluted drills must be used for drilling into solid metal stock.

The three principal parts of a drill are the shank, body, and point. The flutes of a drill afford channels for chips to pass out, carry any lubricant to the point, and provide correct rake to the lips, thereby causing chips to curl tightly to occupy less space.

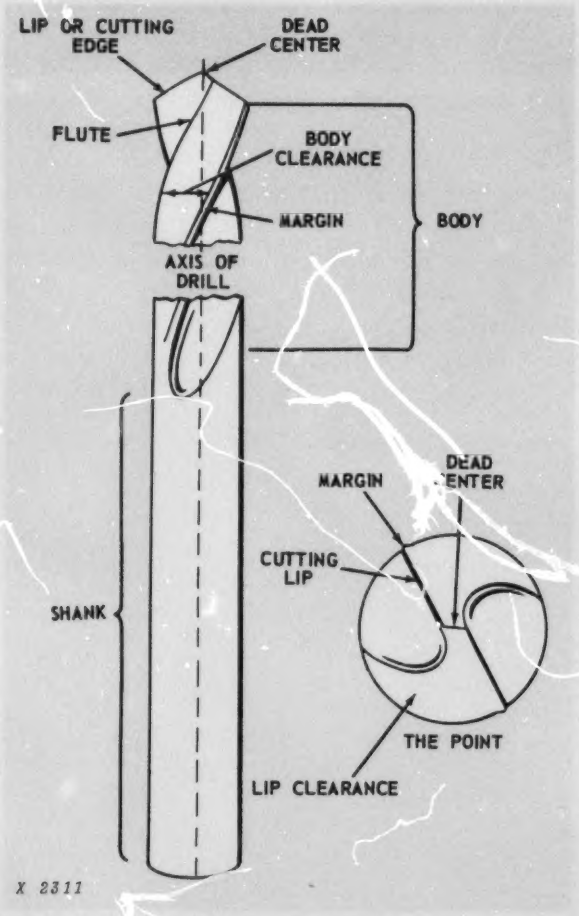


Fig. 53 — Twist Drill

CORRECT USE OF DRILLS

When using a low-speed, slow-feed method of drilling, carbon tool steel drills can be used.

When high-speed or fast-feed of the drill is necessary, use drills of high-speed tool steel.

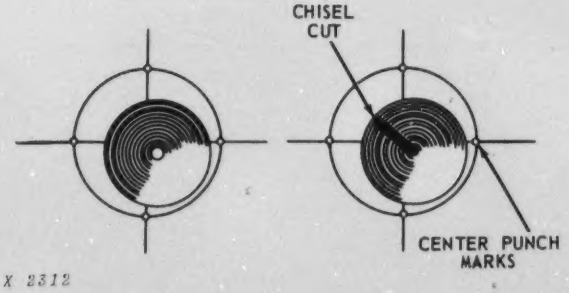


Fig. 54 — How To Draw The Drill Back To Correct Center

Always center punch the exact spot to drill holes accurately.

After the drill has enlarged the center punch mark slightly and before the whole point has entered the material, check to see that the hole is correctly centered. If the drill is not entering the right spot, it can be drawn over by making a chisel cut on the side to which the drill should be drawn (Fig. 54).

Whenever possible, use a lubricant to cool the drill.

GRINDING OR SHARPENING DRILLS

Before using a drill, be sure it is sharp and ground according to the material to be drilled.

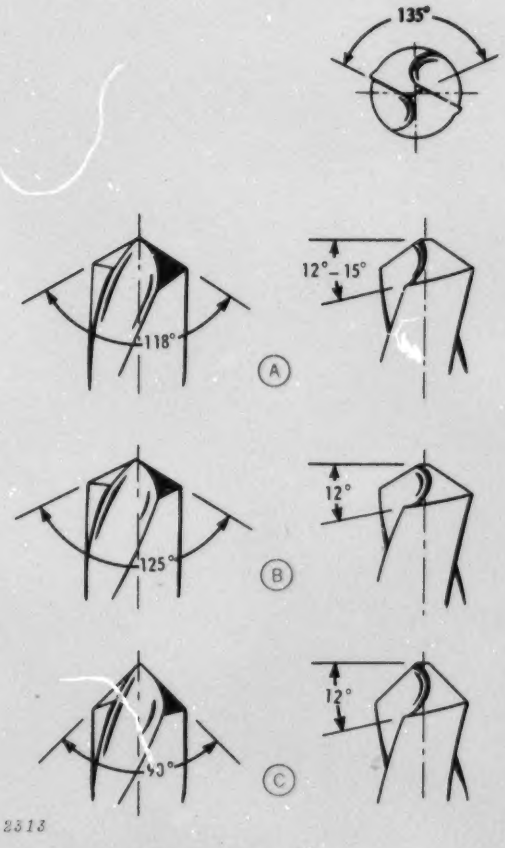


Fig. 55 — Common Shape Of Drills

Fig. 55 illustrates the most commonly used shapes. The *lips* do the cutting and therefore must be ground to a sharp edge. These lips or cutting edges must be of uniform length.

The portion behind lips is ground down on an angle to provide lip clearance (see Fig. 53).

For steel and cast iron, these lips are ground on a 59° angle to the drill axis or 118° included angle as

shown in Fig. 55. Note that lip clearance angle on "A" is 12° to 15°.

"B" illustrates a drill ground to drill heat-treated steels and drop forgings. Note that included angle is greater and lip clearance angle is 12°.

When drilling softer material such as wood, hard rubber, fiber, or soft cast iron, a much smaller included angle can be used as shown at "C".

When any unusual material such as spring steel must be drilled, consult a machinist's handbook to obtain the correct angles and shapes.

Several attachments for grinders are available for grinding drills accurately.

NOTE: Always be sure to keep drills cool while grinding by dipping occasionally in suitable coolant — water or oil.

TAPS AND DIES

Taps are used for cutting internal threads. There are many styles of taps, but for general shop use, a set of taper, plug, bottom and machine screw taps should be provided (Fig. 56).

Each type of tap will have to be provided in both National Fine (NF) and National Coarse (NC) threads, as well as in the various sizes, 1/4, 5/16, etc.

Metric taps are provided in various sizes with the dimension for pitch (distance between threads) also listed. Pitch is listed in place of NC or NF.

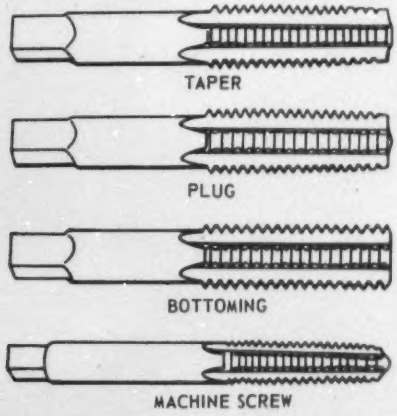


Fig. 56 — Four Kinds Of Taps

The *taper tap* is used to tap completely through the hole. Notice that it has a long gradual taper that allows the tap to start easily.

The *plug tap* is used to tap threads partway through. The *bottoming tap* is used to cut threads all the way to the bottom of a blind hole. The plug tap should precede the bottoming tap, as the bottoming tap will not start well.

The plug tap is the most widely used and, except when running threads completely to the bottom of a blind hole, will work satisfactorily.

The *machine screw tap* handles the small diameter, fine thread jos.

TAP DRILL SIZES
Recommended for
AMERICAN NATIONAL SCREW THREAD PITCHES

COARSE STANDARD THREAD (N. C.)
Formerly U. S. Standard Thread

Sizes	Threads Per Inch	Outside Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	.073	53	0.0595
2	56	.086	50	0.0700
3	48	.099	47	0.0785
4	40	.112	43	0.0890
5	40	.125	38	0.1015
6	32	.138	36	0.1065
8	32	.164	29	0.1360
10	24	.190	25	0.1495
12	24	.216	16	0.1770
1/4	20	.250	7	0.2010
5/16	18	.3125	F	0.2570
3/8	16	.375	5/16	0.3125
7/16	14	.4375	U	0.3680
1/2	13	.500	27/64	0.4219
9/16	12	.5625	31/64	0.4843
5/8	11	.625	17/32	0.5312
3/4	10	.750	21/32	0.6562
7/8	9	.875	49/64	0.7656
1	8	1.000	7/8	0.875
1 1/8	7	1.125	63/64	0.9843
1 1/4	7	1.250	1 7/64	1.1093

FINE STANDARD THREAD (N. F.)
Formerly S.A.E. Thread

Sizes	Threads Per Inch	Outside Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
0	80	.060	3/64	0.0469
1	72	.073	53	0.0595
2	64	.086	50	0.0700
3	56	.099	45	0.0820
4	48	.112	42	0.0935
5	44	.125	37	0.1040
6	40	.138	33	0.1130
8	36	.164	29	0.1360
10	32	.190	21	0.1590
12	28	.216	14	0.1820
1/4	28	.250	3	0.2130
5/16	24	.3125	I	0.2720
3/8	24	.375	Q	0.3320
7/16	20	.4375	25/64	0.3906
1/2	20	.500	29/64	0.4531
9/16	18	.5625	0.5062	0.5062
5/8	18	.625	0.5687	0.5687
3/4	16	.750	11/16	0.6875
7/8	14	.875	0.8020	0.8020
1	14	1.000	0.9274	0.9274
1 1/8	12	1.125	1 3/64	1.0468
1 1/4	12	1.250	1 11/64	1.1718

SPECIAL THREAD (N. S.)

Sizes	Threads Per Inch	Outside Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	56	.0730	54	0.0550
4	32	.1120	45	0.0820
4	36	.1120	44	0.0860
6	36	.1380	34	0.1110
8	40	.1640	28	0.1405
10	30	.1900	22	0.1570
12	32	.2160	13	0.1850
14	20	.2420	10	0.1935
14	24	.2420	7	0.2010
1/8	64	.0625	3/64	0.0469
5/32	48	.0938	49	0.0730
5/32	40	.1250	38	0.1015
5/32	32	.1563	1/8	0.1250
5/32	36	.1563	30	0.1285
3/16	24	.1875	26	0.1470
3/16	32	.1875	22	0.1570
7/32	24	.2188	16	0.1770
7/32	32	.2188	12	0.1890
1/4	24	.250	4	0.2090
1/4	27	.250	3	0.2130
1/4	32	.250	9/64	0.2187
5/16	20	.3125	17/64	0.2656
5/16	27	.3125	J	0.2770
5/16	32	.3125	9/32	0.2812
3/8	20	.375	21/64	0.3281
3/8	27	.375	R	0.3390
7/16	24	.4375	X	0.3970
7/16	27	.4375	Y	0.4040
1/2	12	.500	27/64	0.4219
1/2	24	.500	29/64	0.4531
1/2	27	.500	15/32	0.4687
9/16	27	.5625	17/32	0.5312
5/8	12	.625	35/64	0.5469
5/8	27	.625	19/32	0.5937
11/16	11	.6875	19/32	0.5937
11/16	16	.6875	45/64	0.6250
3/4	12	.750	43/64	0.6719
3/4	27	.750	23/32	0.7187
7/8	12	.875	51/64	0.7969
7/8	18	.875	53/64	0.8281
7/8	27	.875	27/32	0.8437
1	12	1.000	59/64	0.9219
1	27	1.000	31/32	0.9687

Fig. 57 — Tap Drill Size Chart

TAP DRILL SIZES (METRIC)

Bolt Diameter (in mm)	Distance Between Threads (in mm)	Diameter of Drill (in mm)	Bolt Diameter (in mm)	Distance Between Threads (in mm)	Diameter of Drill (in mm)
M 2	0.4	1.6	M 22	2.5	19.5
M 2.2	0.45	1.75	M 24	3	21
M 2.5	0.45	2.05	M 27	3	24
			M 30	3.5	26.5
M 3	0.5	2.5			
M 3.5	0.6	2.9	M 33	3.5	29.5
M 4	0.7	3.3	M 36	4	32
M 4.5	0.75	3.7	M 39	4	35
			M 42	4.5	37.5
M 5	0.8	4.2			
M 6	1	5	M 45	4.5	40.5
M 8	1.25	6.8	M 48	5	43
M 10	1.5	8.5	M 52	5	47
M 12	1.75	10.2	M 56	5.5	50.5
M 14	2	12	M 60	5.5	55
M 16	2	14	M 64	6	58
M 18	2.5	15.5	M 68	6	62
M 20	2.5	17.5			

USING THE TAP

After determining the diameter, and number of threads per inch (pitch for metric) of the screw or stud that will enter the tapped hole, use a tap drill size chart to find what size hole to drill. See Fig. 57.

For example, suppose you find that you want a threaded hole for a 3/8 stud with coarse (National Coarse) threads. Referring to the top chart in Fig. 57, you will find the 3/8 N.C. will have 16 threads per inch. Looking directly across from the 3/8 size, you will find that the tap drill size is listed as 5/16. This means that for a 3/8 N.C. stud, you must drill a hole 5/16 in diameter.

If the hole is to be tapped partway through, use a 3/8 x 16 N.C. plug tap. Place the tap in a tap handle, and carefully start the tap in the hole (Fig. 58). Place some tap lubricant on the tap. After threading the tap in one or two turns, back the tap up about a quarter to one-half turn to break the chip. Repeat this process as your tapping continues.

For an example of using a metric tap, suppose you want a threaded hole for an M 5 stud. Referring to the bottom chart in Fig. 57, you will find the M 5 size will have a pitch of 0.8 mm. Looking directly across from the M 5 size, you will find that the tap drill size is listed as 4.2. This means that for an M 5 stud with a pitch of 0.8 mm, you must drill a hole 4.2 mm in diameter.

Be careful the hole does not clog with chips. It may be necessary to withdraw the tap and remove the chips. Taps are quite brittle. Use them with care, and make certain you use the proper size tap drill.

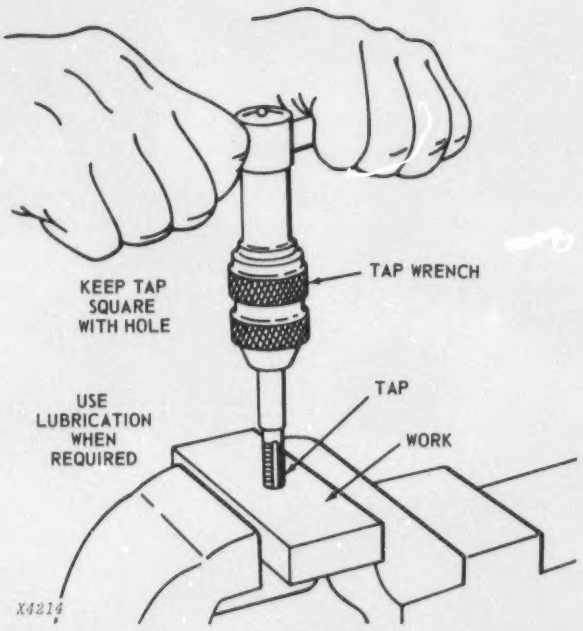


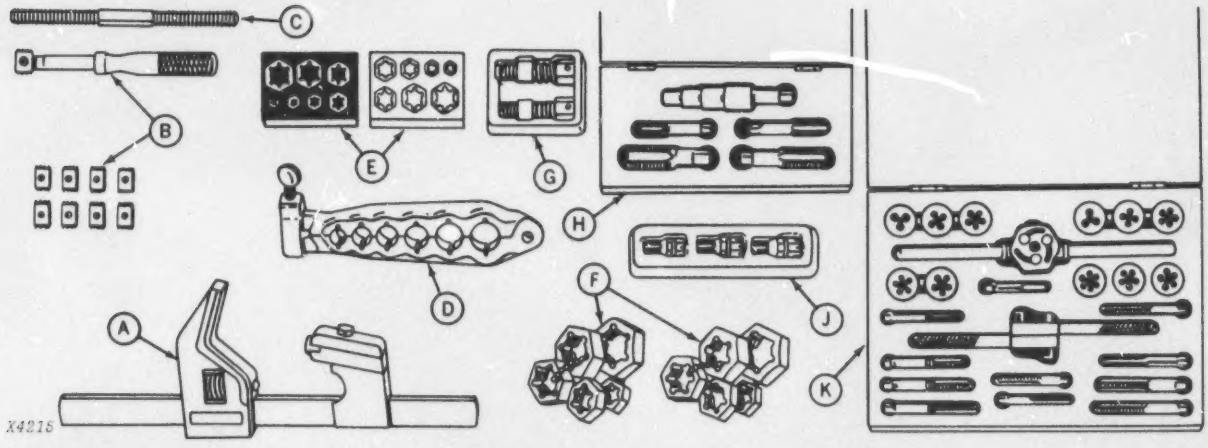
Fig. 58 — Using The Tap To Thread A Drilled Hole

DIES

Dies are used to cut external threads. A die of the correct size is placed in a diestock (handle) and it is turned. Use lubricant, back up every one or two turns, and keep free of chips.

Dies are often adjustable in size so you can enlarge or reduce (slightly) the outside diameter of a threaded area.

Both taps and dies should be cleaned, slightly oiled, and placed in a protective box for storage.



A — Rethreading Tool
B — Internal Thread Chaser
C — Thread Restorer
D — Axle Rethreader
E-F — Rethreading Dies
G-H — Spark Plug Hole Taps
J — Tap and Die Set for Tube Flare Fittings
K — Combination Tap and Die Set

Fig. 59 — Taps and Dies

SPECIAL TAPS AND DIES

The serviceman will also find use for a few special taps and dies as illustrated in Fig. 59.

One form of rethreading tool is shown in A. It is placed on the thread and turned.

B shows an internal thread chaser used to clean up dirty or damaged internal threads.

The thread restorer, C, is handy for quickly reconditioning external threads.

The axle rethreader, D, is placed around the good thread area, clamped shut, and is then turned back over the damaged area.

Nut or rethreading dies, E and F, can be turned on a damaged thread. An ordinary box wrench can be used to turn them.

G and H show spark plug hole taps. These are very handy to clean up damaged or carboned plug hole threads.

A combination tap and die set for tube flare fittings is illustrated in J.

A combination tap and die set is pictured in K.

SCREW EXTRACTORS

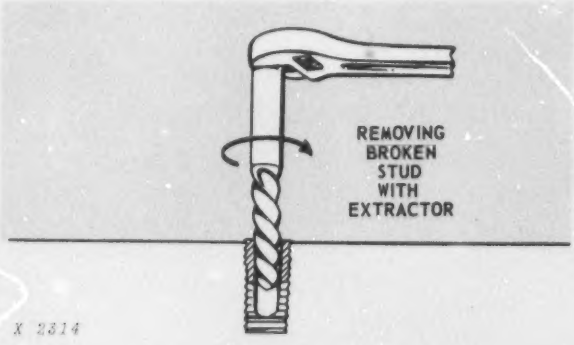


Fig. 60 — Removing Broken Stud With Screw Extractor

To remove *broken* screws or studs, use a screw extractor (Fig. 60). It resembles a reverse-threaded screw.

To use: Drill into the exact center of the broken stud. Be sure the hole is smaller than the inside of the stud threads to avoid damage to threads in the tapped hole. Drill a small pilot hole first for greater accuracy. Turn the extractor into the hole as shown and back out the stud carefully. Extractors are available for most screw sizes.

In an emergency, a diamond-point chisel can be used to remove a broken stud (Fig. 61). Simply drive the chisel into the stud after drilling a small hole into the center of the stud. Then turn the chisel carefully with a wrench.

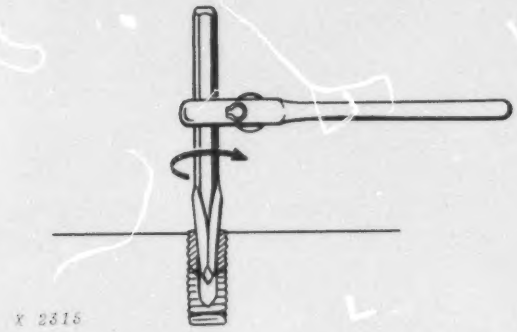


Fig. 61 — Using Chisel As Emergency Stud Remover

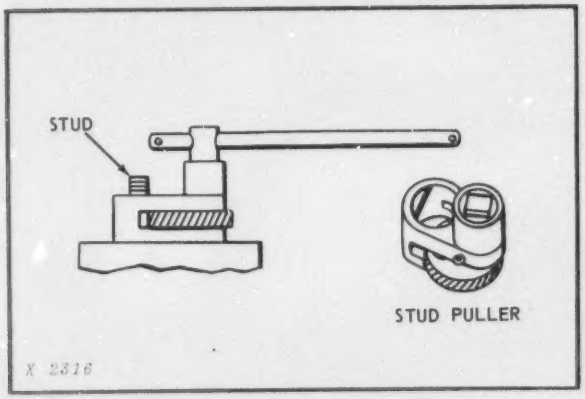


Fig. 62 — Stud Puller For Unbroken Studs

To remove *unbroken* studs, use a stud puller.

To use: Drop the stud puller over the stud to be removed (Fig. 62). Use a tee or flex handle to turn the stud out. The puller automatically grips the stud with a knurled eccentric as pressure is applied. One size fits almost all studs. In all stud removals, ***use a generous amount of penetrating oil.***

PULLERS

Fitted parts can be damaged during removal and installation unless care is taken. Using hammers, pry bars, and chains may only cause more problems. However, special pullers which fit the parts and apply force evenly and smoothly are often the answer (Fig. 63).

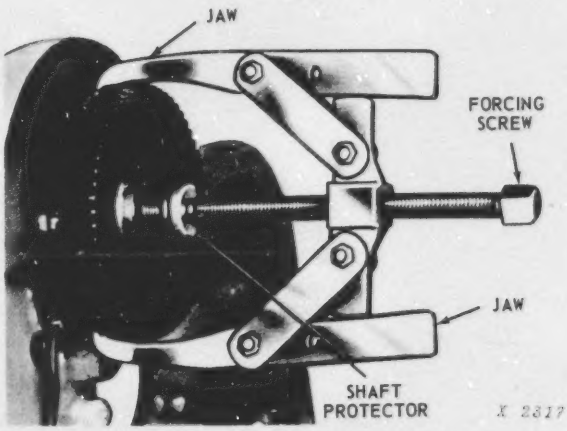


Fig. 63 — Gear Puller

There are three types of pullers (Fig. 64):

- **External puller**
- **Press-puller**
- **Internal puller**

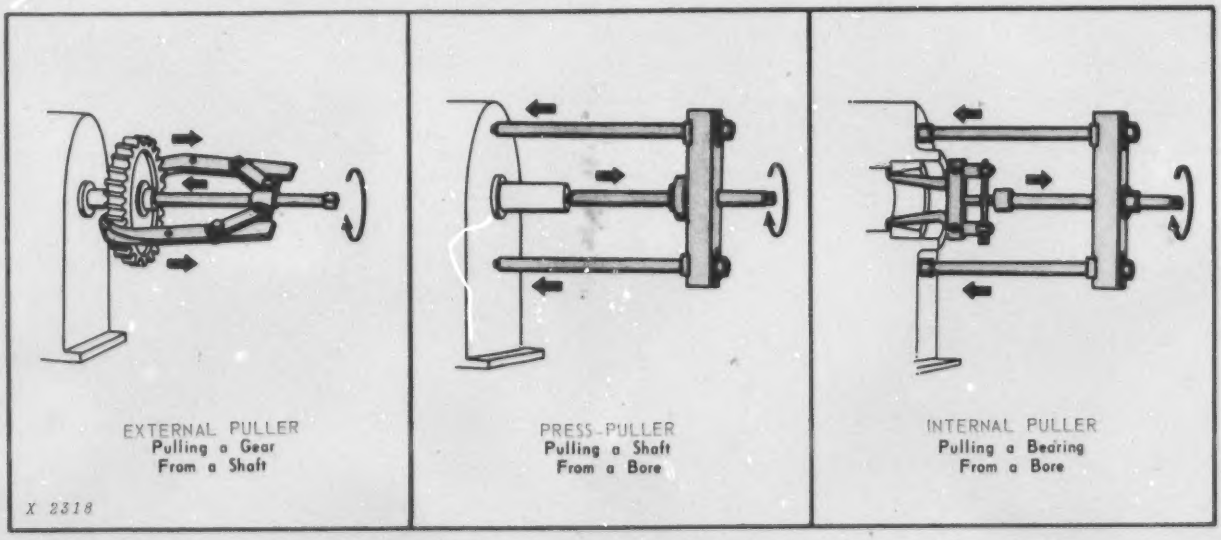


Fig. 64 — Pullers — Three Basic Types

EXTERNAL pullers grip the back of the object with their jaws as shown while the forcing screw pushes against the stationary part, such as a shaft. When the forcing screw is turned, the jaws pull the object.

PRESS-pullers have legs which mount on the stationary part while the object is pulled. As the forcing screw is turned into the object, the object is removed.

INTERNAL pullers also have legs which mount on the stationary part while the forcing screw pulls the object. However, the jaws go *inside* the object and reach *out* to grip it. This puller is commonly used to pull a bearing from a bearing bore as shown.

RULES FOR USE OF PULLERS

1. Don't use a hammer — use a puller. Machined parts and precision bearings which are pressed on can be ruined by forcing them.

2. Don't use a pry bar — use a puller. A puller gives a smooth, even pull and prevents "cocking" the part you are pulling.

3. Choose the right type and size of puller for each job. The main questions are: Can you reach it? Can you grip it? Do you have enough power? This leads you automatically to the type of puller you should use.

4. For special pulling jobs, use a combination puller; for bigger jobs, use a hydraulic puller.

5. Don't overload a puller. A general rule is to use a puller with a forcing screw which is at least one-half the diameter of the shaft.

6. Place a shaft protector over the end of shafts before installing a puller at this point (see Fig. 63).

7. When installing parts which must be forced into place, normally go to a shop press rather than trying to use a puller.

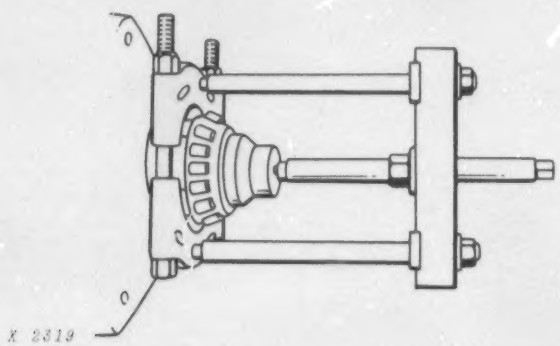


Fig. 65 — Using Knife-Edge Pulling Attachment

When a bearing must be pulled from a shaft, but the bearing is against a flat housing, use a **knife-edge pulling attachment** (Fig. 65). This prevents pulling only on the outer race of the bearing and ruining it.

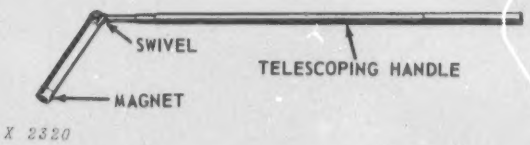


Fig. 66 — Magnetic Pick-Up Tools

These tools (Fig. 66) have a small magnet on the tip. They are handy for retrieving small parts which have fallen into hard-to-reach places such as transmission cases. This may prevent having to strip out a complete unit to recover "stray" parts.

INSPECTION MIRRORS

Inspection mirrors are handy for reaching in and viewing the "blind" side of components, as in closed gear cases. A pin flashlight or a "trouble light" is an extra aid in viewing with the mirror.

TUBING CUTTERS

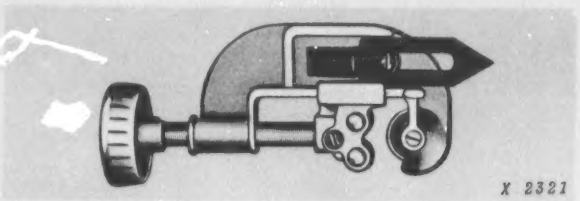


Fig. 67 — Tubing Cutter

These tools (Fig. 67) are used to cut tubing made of copper, aluminum, or steel. As the tool is turned, a sharp wheel cuts into the tubing. Pressure is slowly increased until the tube is cut off cleanly.

The tubing cutter is sometimes sold in a kit which includes a cutter, a tube flaring tool, and a tube bending tool.

SOLDERING EQUIPMENT

Soldering is the process of joining two pieces of metal by using a third metal as an adhesive. Unlike welding, soldering does not involve melting the two metals being joined. Standard solder melts at 800°F (426°C), far below the melting point of most metals.

NOTE: Welding is covered in a separate FOS manual, FOS-52B, on "Welding."

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Most metals can be soldered. The only exceptions are chromium, beryllium, manganese-bronze, and titanium.

There are three methods of soldering:

1. **Soldering iron**
2. **Torch**
3. **Resistance**

In the SOLDERING IRON method, the iron is heated either electrically or in a flame periodically.

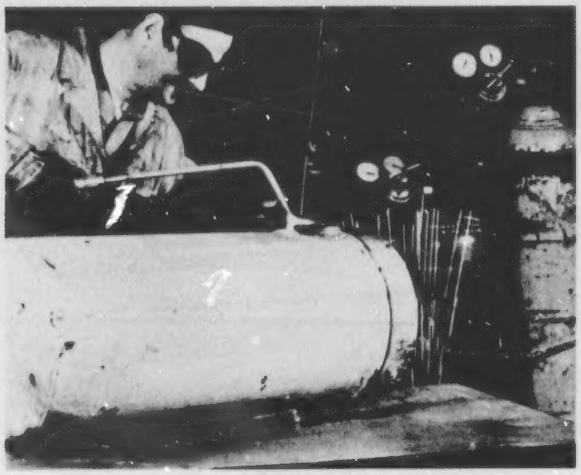

Fig. 68 — Soldering With A Torch

Soldering with a TORCH (Fig. 68) is faster because it produces more heat. Torches are used for soldering heavy sheet metal, pipes, and heavy tubing which require more heat than soldering irons can produce.

RESISTANCE soldering is similar to resistance (spot) welding except that the metals are not melted. Heat created by an electrical current is applied across the joint until the metals are hot enough to melt solder. The solder flows into the joints and the heat is then removed.

SOLDERING MATERIAL

Solder is a mixture of tin and lead — usually equal parts of each. "Hard solder" which melts at a higher temperature, may contain twice as much tin as lead.

Solder is available in stick and in wire rolls. Some types contain their own flux, while others must be dipped in flux or have flux applied to the joint areas. (Flux is a substance such as borax or rosin which helps to fuse the two metals together.)

HOW TO SOLDER

1. Clean the joint thoroughly.

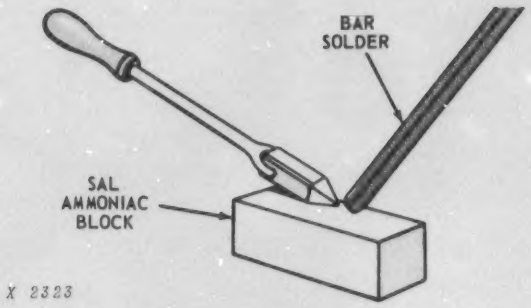

Fig. 69 — Tinning The Soldering Iron

2. Tin the soldering iron by rubbing it on a sal ammoniac block, then touching solder to it (Fig. 69). Or simply heat the soldering iron and touch the solder to it.

3. Heat both pieces to be soldered and apply flux (if flux is not included in the solder).

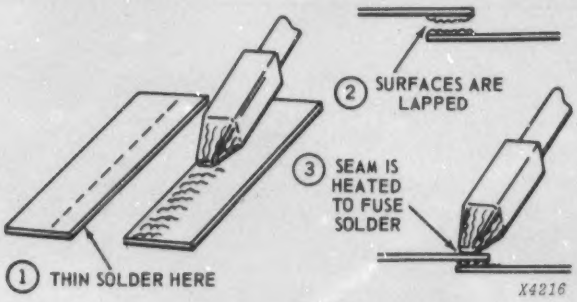

Fig. 70 — Soldering Copper Wires

4. Apply solder to the joints — not to the iron (1, Fig. 70).

5. Lap the two pieces (2) and hold the heated iron over the seam (3) to fuse the solder. Remove heat after the solder has thoroughly penetrated the joint.

6. Hold the two lapped pieces rigid until the solder cools and sets.

FEELER GAUGES

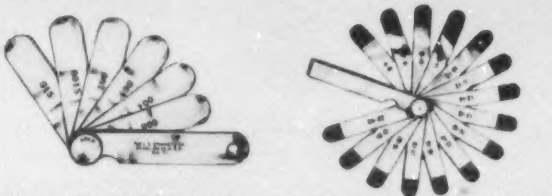

Fig. 71 — Feeler Gauge Sets

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Feeler gauges (Fig. 71) are precision measuring tools for checking small clearances.

Standard feeler gauges have several blades arranged around a common pivot. Thickness of each blade is marked in thousandths of an inch or millimeters.

For example, an ".006" indicates six-thousandths of an inch. A blade marked "6" indicates the same thing. On metric feeler gauges, an 0.15 indicates fifteen-hundredths of a millimeter.

Stepped feeler gauges have blades which have two thicknesses (Fig. 71). The tip of the blade is one thickness, while the rest of the blade is two-thousandths of an inch thicker. These feeler gauges are convenient for making quick, approximate measurements.

For thicknesses more than about 25 thousandths of an inch (1 mm), **wire** feeler gauges are often used. An example is a spark plug gap gauge.

USE OF FEELER GAUGES

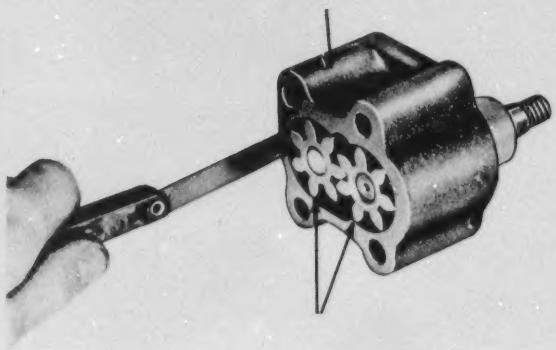

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Fig. 72 — Use Of Feeler Gauge

Never get the blades of the gauge wedged in the clearance space. If the blade being tried cannot enter the space without forcing, use a thinner blade, or adjust clearance to conform.

Never bend or twist the blades. Always move the feeler gauge body in the same plane as the blade being used. Fig. 72 shows a feeler gauge being used correctly.

CARE OF FEELER GAUGES

When in doubt about the thickness of a blade, measure it with a micrometer.

Occasionally wipe the blades clean with an oily cloth to remove dirt and prevent rusting.

MICROMETERS

Micrometers or "mikes" are precision tools which measure in thousandths of an inch.

We will cover four types of micrometers:

- **Outside micrometers**
- **Inside micrometers**
- **Telescope gauges**
- **Depth micrometers**

Let's look at each one in detail.

OUTSIDE MICROMETERS

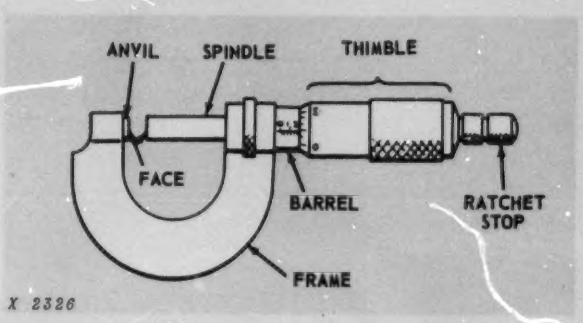

Fig. 73 — Outside Micrometer

An outside micrometer (Fig. 73) is used to measure the size of parts (diameter, thickness, etc.) accurately to within a very minute part of an inch.

How To Use: Before measuring a part, determine the size of micrometer needed. Micrometer sizes are determined by the distance between faces of anvil and spindle when the thimble is screwed to both zero extremes of barrel. An accurate 1- to 2-inch (25 to 50 mm) micrometer will always have a minimum of one inch (25 mm) between faces and a maximum of two inches (50 mm). It cannot be used for measuring a part less than one inch (25 mm) thick.

After selecting the correct micrometer, open it up to a distance a little *greater* than the thickness of the part to be measured. With the micrometer held in one hand, bring it over object to be measured.

NOTE: One or both hands can be used to operate the micrometer.

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Fig. 74 — Correct Use Of Outside Micrometer

Turn thimble lightly between the thumb and first finger until faces of anvil and spindle contact the work (Fig. 74). If the micrometer is equipped with a ratchet stop, turn it until at least two clicks can be heard.

Some micrometers do not have a ratchet stop; in this case a "feel" has to be developed to know when the correct contact pressure is being made by the spindle.

CAUTION: Never tighten spindle so tight that work cannot be drawn from between anvil and spindle.

Do not slide the micrometer back and forth excessively across the work because this will wear away the face of both the anvil and spindle.

If possible, take the reading before removing the micrometer from the work, to obtain a more accurate reading. If the reading cannot be taken before removing the micrometer, remove it very carefully to prevent disturbing the position of the spindle.

In hard-to-reach places, use outside calipers to take a more accurate measure; then transfer to an inside micrometer for the reading.

The graduations on a micrometer will be easier to understand when its construction is known. Micrometers use the principle of accurately cut screw-threads to determine measurement. Fig. 75 shows the barrel and thimble of a micrometer used to measure thousandths of an inch. This micrometer has 40 threads to an inch cut on the barrel and thimble. For construction and use of metric micrometers, see discussion beginning on next page.

Movement of the thimble on the barrel is limited to one inch. One complete revolution of the thimble

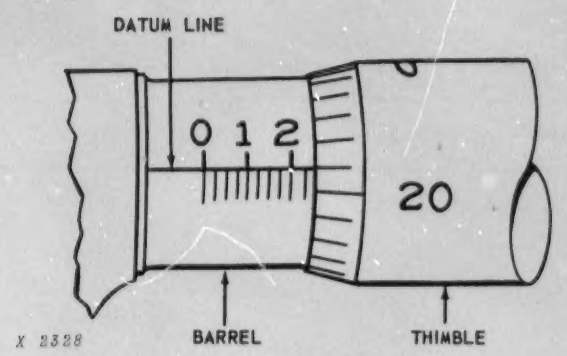


Fig. 75 — Micrometer Graduations

is 1/40 part of an inch or .025 inch. The position of the thimble in relation to barrel is used to read measurements.

The line marked lengthwise on the barrel is known as the revolution or datum line (Fig. 75).

Cross markings on this line show the distance the thimble travels in one revolution, or .025 inch between two lines. Every fourth line is numbered 1, 2, 3, etc., designating .100, .200, .300 etc. inch. The thimble is marked and divided into 25 equal parts. Each time the space between two lines on the thimble passes the datum line, the spindle moves 1 thousandth inch (.001 inch). Every fifth line on the thimble is numbered 0, 5, 10, 15, and 20.

Following is an example of a reading taken from Fig. 75:

Highest figure whose reference line is visible on barrel — 2, this equals ..... .200 inch
Number of lines visible on barrel beyond highest figure — 1. This equals ..... .025 inch
Line on thimble aligning with revolution of datum line — 21, this equals ..... .021 inch
Total ..... .246 inch

If the line on the thimble does not align with the datum line, use the value which comes closest to it, or estimate the fraction of a thousandth over the line on the thimble below the datum line.

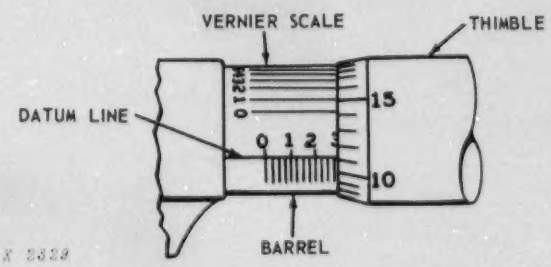


Fig. 76 — Micrometer With Vernier Scale

If more accurate readings are desired, use a **vernier** micrometer (Fig. 76). This micrometer has a vernier scale on the barrel which divides thousandths on the thimble into tenths making it possible to make a measurement to one *ten*-thousandth inch (.0001 inch).

Take the value of the line on the thimble which falls below the datum line and add to this the value of the vernier scale reading. To determine the vernier scale reading, look along the edge of the thimble and find any vernier line and thimble line which coincide. For example, if the vernier line number 2 is found to coincide with a line on the thimble, then the vernier value is .0002.

Following is an example of a reading taken from Fig. 76:

Highest figure whose reference line is visible in the barrel — 2. This equals ..... .200 inch

Number of lines visible beyond highest figure — 3. This equals ..... .075 inch

Line on the thimble below the datum line — 11. This equals ..... .011 inch

Vernier line coinciding with line on thimble — 2. This equals ..... .0002 inch

Total ..... .2862 inch

Movement of the thimble on the barrel is limited to 25 mm. One complete revolution of the thimble is 0.5 mm. The position of the thimble in relation to barrel is used to read measurements.

Scales on metric micrometers are the same as on conventional micrometers except that measurements are in millimeters instead of inches.

Cross markings appear below the datum line in Fig. 77 and show the distance the thimble travels in one revolution, or 0.5 mm between lines. Every tenth line is numbered 5, 10, 15, etc. designating 5, 10, 15 mm, etc. The thimble is marked and divided into 50 equal parts. Each time the space between two lines on the thimble passes the datum line, the spindle moves one hundredth of a millimeter (0.01 mm). Every fifth line on the thimble is numbered 5, 10, 15, 20, etc.

Following is a reading taken from Fig. 77:

Highest figure whose reference line is visible on barrel — 5. This equals ..... 5.00 mm

Number of lines visible on barrel beyond highest figure — 3. This equals ..... 1.50 mm

Line on thimble aligning with revolution of datum line — 11. This equals ..... 0.11 mm

Total ..... 6.61 mm

If the line on the thimble does not align with the datum line, use the value which comes closest to it, or estimate the fraction of a hundredth over the line on the thimble below the datum line.

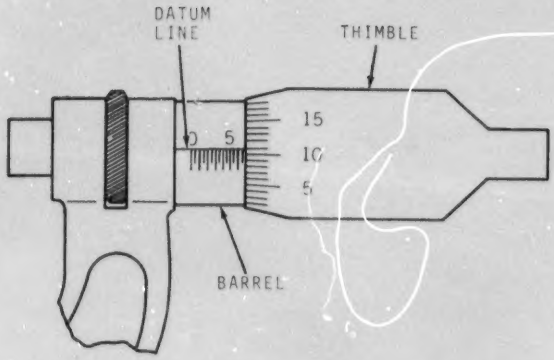


Fig. 77 — Barrel and Thimble of Metric Micrometer

METRIC MICROMETERS

Fig. 77 shows the barrel and thimble of a metric micrometer used to measure hundredths of a millimeter. This micrometer contains threads every 0.5 mm.

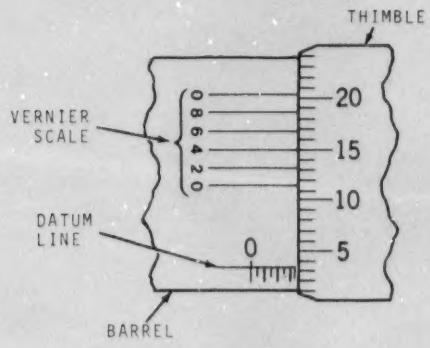


Fig. 78 — Vernier Micrometer

If more accurate readings are desired, use a **vernier micrometer** (Fig. 78). The vernier scale divides hundredths on the thimble into tenths, making it possible to measure to one thousandth millimeter.

Take the value of the line on the thimble which falls below the datum line and add to this value of the vernier scale reading. To determine the vernier scale reading, look along the edge of the thimble and find any vernier line and thimble line which coincide. For example, if the vernier line number 2 is found to coincide with a line on the thimble, then the vernier value is 0.0002.

Following is an example of a reading taken from Fig. 78:

Highest figure whose reference line is visible in the barrel — 0. This equals ..... 0 mm

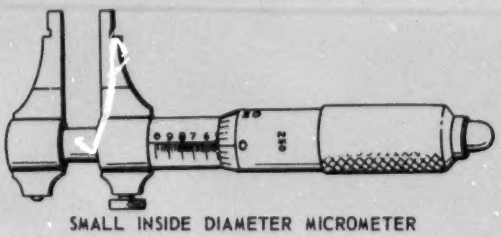
Number of lines visible beyond the highest figure — 7. This equals ..... 3.5 mm

Line on thimble below the datum line — 3. This equals ..... 0.03 mm

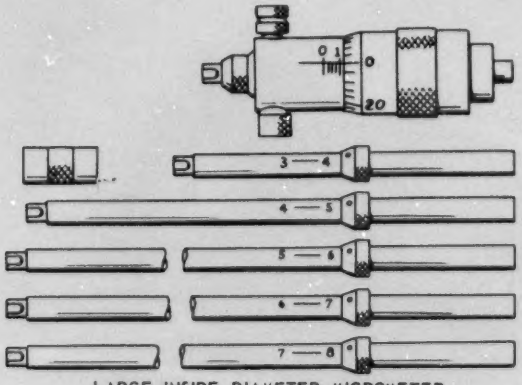
Vernier line coinciding with line on thimble — 4. This equals ..... 0.004 mm

Total 3.534

INSIDE MICROMETERS



SMALL INSIDE DIAMETER MICROMETER



LARGE INSIDE DIAMETER MICROMETER

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Fig. 79 — Inside Micrometers

There are two types of inside micrometers: One for measurng small diameters and one for large diameters (Fig. 79).

Each type is read exactly like the outside micrometer and must receive the same care.

CAUTION: Never adjust an inside micrometer so tight that it cannot be withdrawn from the work.

In hard-to-reach places, use an inside caliper to take the measure; then transfer to an outside micrometer for the reading.

TELESCOPE GAUGE

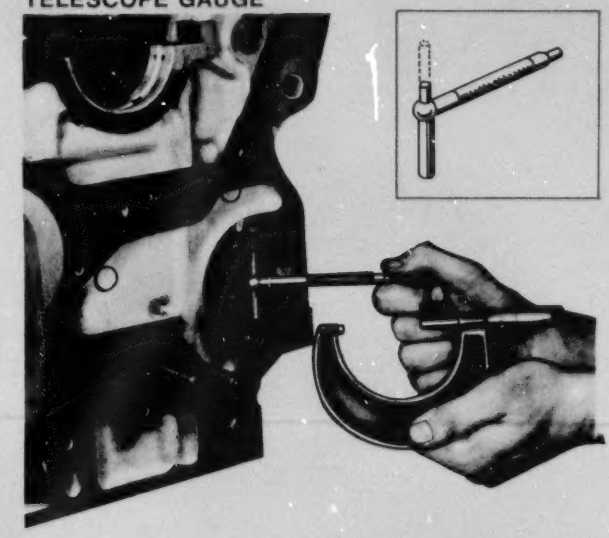

Fig. 80 — Telescope Gauge

The telescope gauge (Fig. 80) is used to measure bores or openings. Place gauge in opening, expand to proper setting, lock by turning stem. This gauge has no scale markings. Measure the setting with an outside micrometer.

DEPTH MICROMETER

Depth micrometers (Fig. 81) are used to measure the depth of openings.

Place the base of the micrometer firmly on the flat surface and turn down the thimble until the pin just touches the bottom of opening. Take the reading in the same way as with an outside micrometer.

When using micrometers, you must convert fractions to their decimal equivalents. (Refer to the decimal chart at the end of this chapter.)

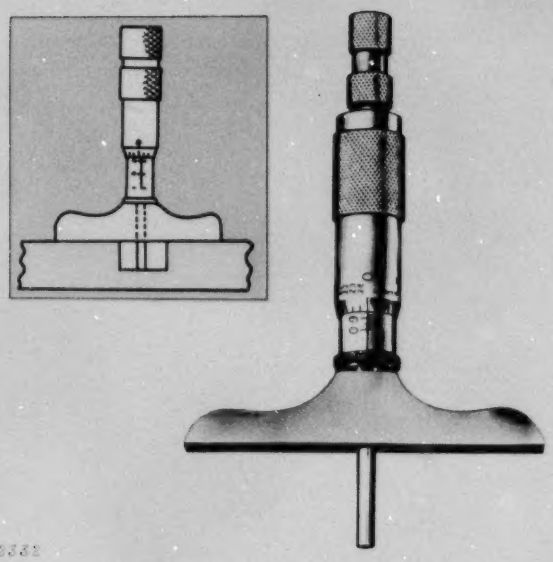

Fig. 81 — Using Depth Micrometer

CARING FOR MICROMETERS

1. Avoid placing micrometers where they will become heated. This will affect their accuracy.

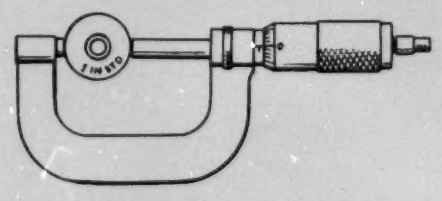

Fig. 82 — Checking Micrometer With Standard

2. Check micrometers periodically with a master gauge or standard, to assure accuracy (Fig. 82).

3. Keep micrometers in a case or box when not in use. This will protect them from grit and dirt.

4. Never allow a micrometer to become rusty or dirty. Wipe with a clean cloth oiled with a few drops of fine machine oil.

5. Always be sure micrometer faces which contact the work are clean before measuring. Never use anything abrasive for wiping faces clean.

CAUTION: If a micrometer is accidently dropped, never use it again until it has been checked on a master gauge or standard.

DIAL INDICATORS

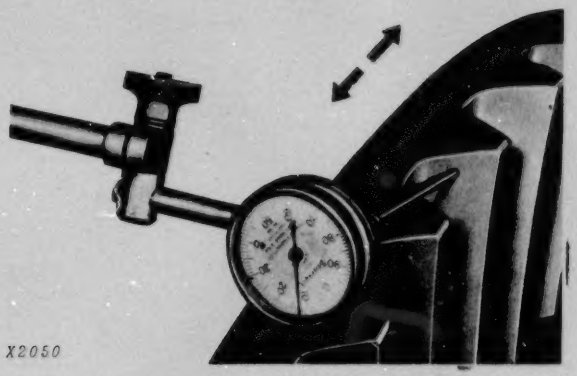

Fig. 83 — Dial Indicator Measuring Backlash On A Gear

Dial indicators measure the movement in shafts or gears which have adjustable endplay or backlash (Fig. 83).

Some indicators have C-clamps for mounting them, while other have a magnetic mount.

Be sure to mount the indicator securely and at right angles to the moving part. This will assure that the full movement is registered on the dial.

To record the full movement also be sure to pry the parts in *both* directions, noting the full range of movement on the indicator dial.

SPRING TESTERS

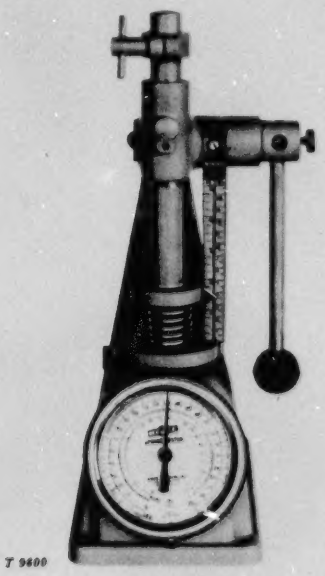

Fig. 84 — Using A Spring Tester

Spring testers check springs for resiliency to see if they match the specifications. Engine valve springs, for example, should all be of uniform strength to allow the valves to work smoothly.

To use the tester (Fig. 84), insert the spring, pull on the lever to compress the spring to the specified compressed length, and read on the dial the pounds of pressure exerted.

Never use the stop on the tester to fix the length to which the spring is to be compressed. The stop should only be used when comparing one spring with another.

CARING FOR SPRING TESTERS

Zero is adjustable on most spring testers by moving a small lever or other device on the dial.

Normally, the pointer can also be tapped into position if it does not match the zero mark after the adjustment above.

Check the scale pointer occasionally to make sure it is correct.

PRESSURE GAUGES

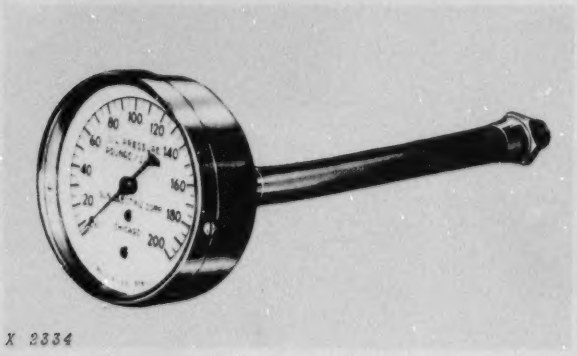

Fig. 85 — Pressure Gauge (Oil Pressure Type Shown)

Pressure gauges (Fig. 85) measure the force exerted on a container by the liquid or gas within it. This is usually called "pounds per square inch" or "psi" (kilopascal or kPa in metric).

Pressure gauges include those to check oil pressure (shown), tire air pressure, compression pressure, cooling system pressure, and fuel pressure.

Gauges may be permanent or hand-held (as shown). Some gauges show only immediate pressure, while others indicate the last-checked pressure until reset.

Pressure gauges should never be oiled. However, keep out all dirt and corrosion to assure an accurate reading.

SPEED-MEASURING TOOLS

Shop tools used for measuring speed are:

- **Revolution Counters**
- **Tachometers**
- **Stroboscopes (Timing Lights)**
- **Oscilloscopes**

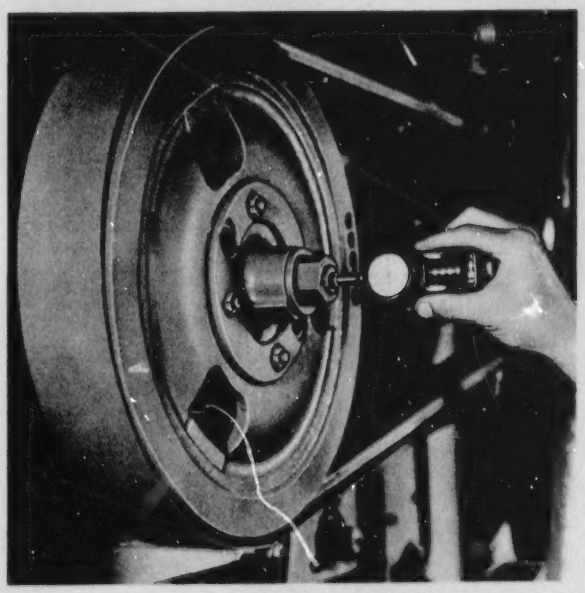

Fig. 86 — Mechanical Revolution Counter

The simplest tool for measuring speeds is the **mechanical revolution counter** (Fig. 86). When taking a reading, the rubber-tipped shaft is pressed against the end of the revolving shaft for a set period of time. The number of revolutions is noted on the dial and figured as revolutions per minute (rpm).

Tachometers (Fig. 87) do the same job as counters, except that they show the revolutions multiplied by time (as rpm). Another example of this is the common speedometer, which indicates wheel revolutions per hour, computed in miles per hour (mph). Tachometers on most machines, however, give engine speed in revolutions per minute (rpm).

The **stroboscope** gives speed of rotation or vibration. It does not touch the device it is checking, but uses a rapidly flashing light. To determine the

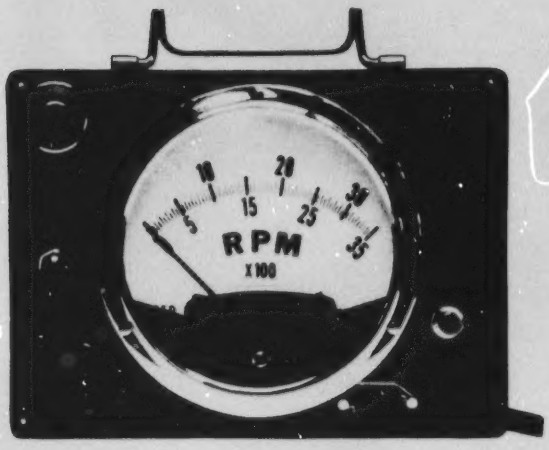

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Fig. 87 — Portable Electronic Tachometer

Fig. 88 — Special Tools Are Also Needed To Completely Equip The Shop

rotating speed of a shaft, for example, the speed of the flashing light is adjusted until the shaft appears to stand still. In other words, the speed of the shaft is synchronized to the flashing light. The speed of the shaft can then be read on the dial of the stroboscope.

A **timing light** operates the same as a stroboscope except that it receives its power and timing impulses from the machine being tested. Timing lights are commonly used to test and adjust the ignition timing of engines.

An **oscilloscope** measures speeds from slow heart beats to high ratio frequencies. It is widely used in testing the vibrations in various parts of a test engine or other components. A common time signal (such as a 60-cycle current) is used for comparison against the unknown time cycle. This comparison is displayed on a cathode ray tube.

SPECIAL TOOLS

There is one category of shop tools that we have not covered — the **special tools** recommended for specific jobs in the shop. This includes both test equipment and specialized repair tools.

In this chapter we have covered only the *basic* shop tools which are widely used in the shop. For more complex tools, refer to the FOS manuals on such subjects as "Electrical Systems" and "Engines." And for special repair tools, refer to the machine Technical Manual when performing the job.

SAFETY RULES

Here is a summary of the safety rules for using shop tools:

1. USE RIGHT TOOL. Don't force small tools to do the job of a heavy-duty tool.

2. MAINTAIN TOOLS WITH CARE. Keep tools sharp or well-adjusted, and clean them periodically. Be sure handles are securely fastened.

3. USE SAFETY GLASSES with many tools. Also use a face or dust mask if a cutting operation is dusty.

4. KEEP GUARDS IN PLACE and in working order.

5. KEEP CHILDREN AWAY. All shop visitors should be kept a safe distance from the work area.

6. KEEP WORK AREA CLEAN. Cluttered areas and benches invite accidents.

7. STORE IDLE TOOLS. When not in use, tools should be stored — out of the way. Disconnect all power tools when not in use.

8. WEAR PROPER APPAREL. Loose clothing can get caught in moving parts.

9. SECURE WORK. Use clamps or a vise to hold work. It's safer than using your hands and it frees both hands to operate the tool.

10. DON'T FORCE TOOL. It will do the job better and safer at the rate for which it was designed.

11. DON'T OVERREACH. Keep proper footing and balance at all times.

12. PULL ON WRENCHES — DON'T PUSH. If you must push, use the base of the palm and hold your hand open. This will save knuckles.

13. HOLD POINTED TOOLS AWAY FROM YOUR BODY. This will avoid possible injury if the tool slips.

14. GROUND ALL POWER TOOLS. Use a three-pronged plug or an adapter with wire attached to a *known ground*.

15. HAVE GOOD LIGHTING AND VENTILATION. Be sure bench areas are well-lit and that exhaust fumes are drawn out of the shop.

16. KEEP A FIRST-AID KIT HANDY. Treat all minor injuries at once to prevent infection.

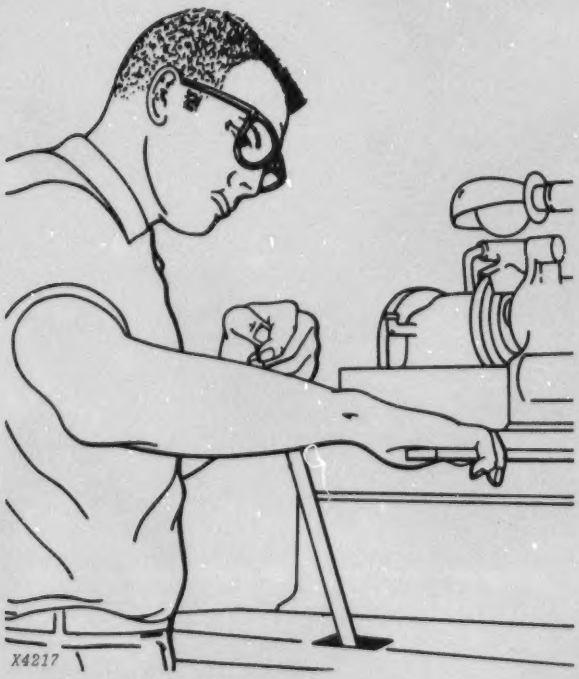

Fig. 89 — Use Safety Glasses and Shields When Grinding

TEST YOURSELF

QUESTIONS

1. True or false? "If a screwdriver bit becomes rounded or broken, it can be regound."

2. What type of hammer should be used on machined surfaces?

3. True or false? "Pliers are used for tightening and loosening small nuts."

4. Should you normally pull or push on a wrench?

5. Why are the heads of open-end wrenches made with an offset?

6. True or false? "Adjustable wrenches can be used exactly like open-end wrenches by 'flopping' them over for a new swing."

7. Match the three pairs of items below:

a. Torque	1. Straight pull	a. Foot-pounds (N·m)
b. Tension	2. Turning force	b. Pounds (N)

8. If a torque reading calls for 5 foot-pounds, how much is that in inch-pounds?

9. Which is the higher strength bolt — one with three dash marks on its head, or one with six dashes?

10. When grinding a chisel (or a screwdriver bit) why should you *not* hold it against the grinding wheel for any great length of time?

11. When filing, should you do the cutting on the pushing or the pulling stroke?

12. When placing a hacksaw blade in its frame, should the saw teeth point toward the handle or away from it?

13. At least how many teeth should always contact the material when using a hacksaw?

14. What are the three types of pullers?

15. When pulling a bearing that is mounted against a flat housing, what attachment should be used with the puller?

16. Explain how two metals are joined when soldering.

17. What does a "6" indicate on the blade of a feeler gauge?

18. True or false? "When taking a reading with an outside micrometer, clamp it tightly over the work to be sure of an accurate reading."

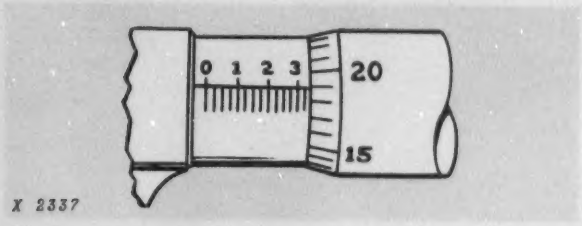

Fig. 90 — Micrometer Reading

19. What is the measurement shown on the micrometer in Fig. 90?

20. What does "psi" mean? kPa?

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WEIGHTS AND MEASURES

Here are most of the dimensions you will need in everyday shop work.

FRACTIONS, DECIMALS AND MILLIMETERS CHART

Inches		mm	Inches		mm
1/64	.016	0,40	33/64	.516	13,10
1/32	.031	0,79	17/32	.531	13,49
3/64	.047	1,19	35/64	.547	13,89
1/16	.062	1,59	9/16	.562	14,29
5/64	.078	1,98	37/64	.578	14,68
3/32	.094	2,38	19/32	.594	15,08
	.100	2,54		.600	15,24
7/64	.109	2,78	39/64	.609	15,48
1/8	.125	3,18	5/8	.625	15,88
9/64	.141	3,57	41/64	.641	16,27
5/32	.156	3,97	21/32	.656	16,67
11/64	.172	4,37	43/64	.672	17,07
3/16	.188	4,76	11/16	.688	17,46
13/64	.203	5,16	45/64	.703	17,86
7/32	.219	5,56	23/32	.719	18,26
15/64	.234	5,95	47/64	.734	18,65
1/4	.250	6,35	3/4	.750	19,05
17/64	.266	6,75	49/64	.766	19,45
9/32	.281	7,14	25/32	.781	19,84
19/64	.297	7,54	51/64	.797	20,24
5/16	.312	7,94	13/16	.812	20,64
21/64	.328	8,33	53/64	.828	21,03
11/32	.344	8,73	27/32	.844	21,43
23/64	.359	9,13	55/64	.859	21,83
3/8	.375	9,53	7/8	.875	22,23
25/64	.391	9,92	57/64	.891	22,62
	.400	10,16		.900	22,86
13/32	.406	10,32	29/32	.906	23,02
27/64	.422	10,72	59/64	.922	23,42
7/16	.438	11,11	15/16	.938	23,81
29/64	.453	11,51	61/64	.953	24,21
15/32	.469	11,91	31/32	.969	24,61
31/64	.484	12,30	63/64	.984	25,00
1/2	.500	12,70	1	1.000	25,40

WEIGHT MEASURE

1 Gross or Long Ton = 2,240 Lbs.
1 Net or Short Ton = 2,000 Lbs.
1 Cubic Foot of Water = 62.5 Lbs.
1 Gallon of Water = 8.33 Lbs.

SQUARE MEASURE

1 Township = 36 Square Miles
1 Square Mile = 640 Acres
1 Acre = 4,840 Square Yards
1 Acre = 43,560 Square Feet
1 Square Yard = 9 Square Feet
1 Square Foot = 144 Square Inches
1 Hectare = 2.471 Acres

SURVEYOR'S MEASURE

1 Link = 7.92 Inches
1 Rod = 25 Links
1 Chain = 4 Rods
1 Acre = 10 Square Chains
1 Acre = 160 Square Rods
1 Township = 36 Square Miles (6 Miles Square)

LENGTH MEASURE

1 Mile = 8 Furlongs
1 Mile = 80 Chains
1 Mile = 320 Rods
1 Mile = 1,760 Yards
1 Furlong = 10 Chains
1 Furlong = 220 Yards
1 Station = 6.06 Rods
1 Station = 33.3 Yards
1 Station = 100 Feet
1 Chain = 4 Rods
1 Chain = 22 Yards
1 Chain = 66 Feet
1 Chain = 100 Links
1 Rod = 5.5 Yards
1 Rod = 16.5 Feet
1 Yard = 3 Feet
1 Yard = 36 Inches
1 Foot = 12 Inches

CUBIC MEASURE

1 Cubic Foot = 1,728 Cubic Inches
1 Cubic Yard = 27 Cubic Feet

DRY MEASURE

2 Pints = 1 Quart
8 Quarts = 1 Peck
4 Pecks = 1 Bushel
1 Bushel = 2,150.42 Cubic Inches

FLUID MEASURE

1 Teaspoon = 1/3 Tablespoon
1 Tablespoon = 1/2 Ounce
2 Cups = 1 Pint
16 Ounces = 1 Pint
2 Pints = 1 Quart
4 Quarts = 1 Gallon
1 Gallon = 231 Cubic Inches
1 Gallon = .1337 Cubic Foot
1 Cubic Foot = 7.5 Gallons

METRIC AND ENGLISH CONVERSION TABLE

1 kilometer = 0.6214 mile

1 meter = (39.37 inches
(3.2808 feet
(1.0936 yards

1 centimeter = 0.3937 inch

1 millimeter = 0.03937 inch

1 mile = 1.609 kilometer

1 yard = 0.9144 meter

1 foot = 0.3048 meter

1 foot = 304.8 millimeters

1 inch = 2.54 centimeters

1 inch = 25.4 millimeters

TABLES OF METRIC WEIGHTS AND MEASURES

Weight Measure

10 milligrams ..... 1 centigram (cg.)

10 centigrams . 1 decigram (dg.) — 100 milligrams

10 decigrams ..... 1 gram (g.) — 1,000 milligrams

10 grams ..... 1 dekagram (dkg.)

10 dekagrams ... 1 hectogram (hg.) — 100 grams

10 hectograms ... 1 kilogram (kg.) — 1,000 grams

1,000 kilograms ..... 1 metric ton (t.)

Volume Measure

10 milliliters (ml.) ..... 1 centiliter (cl.)

10 centileters .... 1 deciliter (dl.) — 100 milliliters

10 deciliters ..... 1 liter (l.l) — 1,000 milliliters

10 liters ..... 1 dekaliter (dkl.)

10 dekaliters ..... 1 hectoliter (hl.) — 100 liters

10 hectoliters ..... 1 kiloliter (kl.) — 1,000 liters

Linear Measure

10 millimeters (mm.) ..... 1 centimeter (cm.)

10 centimeters ..... 1 decimeter (dm.)
— 100 millimeters

10 decimeters ... 1 meter (m.) — 1,000 millimeters

10 meters ..... 1 dekameter (dkm.)

10 dekameters .. 1 hectometer (hm.) — 100 meters

10 hectometers . 1 kilometer (km.) — 1,000 meters

Area Measure

100 square millimeters (mm^2) ..... 1 square centimeter (cm^2)

10,000 square centimeters ... 1 square meter (m^2)
— 1,000,000 square millimeters

100 square meters ..... 1 are (a)

100 ares ... hectare (ha.) — 10,000 square meters

100 hectares ..... 1 square kilometer (km^2.)
— 1,000,000 square meters

Cubic Measure

1,000 cubic millimeters (mm^3) ... cubic centimeter (cm^3)

1,000 cubic centimeters .. 1 cubic decimeter (dm^3)
— 1,000,000 cubic millimeters

1,000 cubic decimeters ..... 1 cubic meter (m^3)
1 stere — 1,000,000 cubic centimeters
— 1,000,000,000 cubic millimeters

TEMPERATURE CONVERSION CHART

Temperatures are given in **Centigrade (C)** or **Fahrenheit (F).** Use the chart below for quickly converting from one to the other.

Degrees C.	Degrees F.
0	32
30	86
100	212

Conversion Formulas

To convert Centigrade to Fahrenheit, multiply by 9/5 and add 32.

To convert Fahrenheit to Centigrade, subtract 32 and multiply by 5/9.

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FASTENER TORQUE GUIDE

Fastener	Type	Minimum Tensile Strength	Material	Body Size or Outside Diameter									
				2	3	4	5	6	8	10	1/4	5/16	3/8
	SAE 2 STEEL	74,000 PSI	LOW CARBON								6 (8)	12 (16)	20 (27)
	SAE 5 STEEL	120,000 PSI	MEDIUM CARBON HEAT TREAT								10 (14)	19 (26)	33 (45)
	SAE 7 STEEL	133,000 PSI	MEDIUM CARBON ALLOY								13 (18)	25 (34)	44 (60)
	SAE 8 STEEL	150,000 PSI	MEDIUM CARBON ALLOY								14 (19)	29 (39)	47 (64)
	SOCKET HEAD CAP SCREW	160,000 PSI	HIGH CARBON QUENCHED TEMPERED								16 (22)	33 (45)	54 (73)
	SOCKET SET SCREW	212,000 PSI	HIGH CARBON QUENCHED TEMPERED					9*	16*	30*	70*	140*	18 (24)
	MACHINE SCREW STAINLESS		18-8	2.6* (294)	4* (452)	5.5* (622)	8* (904)	10* (1130)	20* (2260)	23* (2599)	75* (8475)	132* (14916)	20 (27)
	MACHINE SCREW STAINLESS		316	2.7* (305)	4* (452)	5.7* (644)	8* (904)	10* (1130)	22* (2486)	25* (2825)	80* (9040)	140* (15820)	22 (30)
	MACHINE SCREW YELLOW BRASS	60,000 PSI	CU 63 ZN 37	2* (226)	3.3* (3729)	4.4* (497)	6.4* (723)	8* (904)	16* (1808)	20* (2260)	65* (7345)	110* (12430)	17 (23)
	SILICONE BRONZE TYPE "B"	70,000 PSI	CU 96 ZNI - 5 MIN	2.3* (260)	3.7* (418)	4.9* (554)	7.2* (814)	10* (1130)	19* (2147)	22* (2488)	70* (7910)	125* (14125)	20 (27)
	MACHINE SCREW ALUMINUM	55,000 PSI	CU 3.8-4.9 1.2-1.6 MN .3-.9	1.4* (158)	2.1* (237)	2.9* (328)	4.3* (486)	5.4* (610)	12* (1356)	15* (1695)	46* (5198)	82* (9266)	13 (18)
	MACHINE SCREW MONEL	82,000 PSI	NI 67 CU 30 FE 1.4	2.5* (283)	4* (452)	5.5* (622)	8* (904)	11* (1243)	21* (2373)	27* (3051)	87* (9831)	155* (17515)	23 (31)
	SEM 5 HEAT TREATED STEEL	120,000 PSI	1018 1022	4* (452)	5* (565)	7* (791)	11* (1243)	15* (1695)	27* (3051)	37* (4181)	90* (10170)	200* (22600)	330* (37290)
	STUDS	Use SAE 2, 5 and 8 values when grade is known, with nut of sufficient strength.											
	TAPPING SCREW	Set up joint as it will be in production. Use 70% of overtorque failure as production specifications.											

X4218

Body Size or Outside Diameter																		
7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/4	2 1/2	2 3/4	3
32 (43)	47 (64)	69 (94)	96 (130)	155 (210)	206 (279)	310 (420)	480 (651)	675 (915)	900 (1220)	1100 (1492)	1470 (1993)	1900 (2576)	2360 (3200)	2750 (3729)	3450 (4678)	4400 (5966)	7350 (9967)	9500 (12882)
54 (73)	78 (106)	114 (155)	154 (209)	257 (348)	382 (518)	587 (796)	794 (1077)	1105 (1498)	1500 (2034)	1775 (2407)	2425 (3288)	3150 (4271)	4200 (5696)	4550 (6170)	6550 (8882)	7175 (9729)	13000 (17628)	16000 (21696)
71 (96)	110 (149)	154 (209)	215 (292)	360 (488)	570 (773)	840 (1139)	1325 (1797)	1825 (2475)	2500 (3390)	3000 (4068)	4000 (5424)	5300 (7187)	7000 (9492)	7500 (10170)	11000 (14916)	15500 (21018)	21000 (28476)	27000 (36612)
78 (106)	119 (161)	169 (229)	230 (312)	380 (515)	600 (814)	700 (949)	1430 (1939)	1975 (2678)	2650 (3593)	3200 (4339)	4400 (5966)	5650 (7661)	7600 (10306)	8200 (11119)	12000 (16272)	17000 (23052)	23000 (31188)	29000 (39324)
84 (114)	125 (170)	180 (244)	250 (339)	400 (542)	640 (868)	970 (1315)	1520 (2061)	2130 (2888)	2850 (3865)	3450 (4678)	4700 (6373)	6100 (8272)	8200 (11119)	8800 (11933)	13000 (17628)	18000 (24408)	24000 (32544)	31000 (42036)
29 (39)	43 (58)	63 (85)	100 (136)	146 (198)														
31 (42)	43 (58)	58 (79)	95 (129)	130 (176)	194 (263)	260 (353)	400 (542)	500 (678)		725 (983)								
34 (46)	46 (62)	60 (81)	100 (136)	135 (183)	210 (285)	280 (380)	425 (576)	515 (698)		750 (1017)								
27 (37)	37 (50)	49 (66)	78 (106)	104 (141)	160 (217)	215 (292)	325 (441)	400 (542)		595 (807)								
30 (41)	41 (56)	53 (72)	88 (119)	117 (159)	180 (244)	250 (339)	365 (495)	450 (610)		655 (888)								
20 (27)	27 (37)	36 (49)	62 (84)	83 (113)	128 (174)	170 (231)	255 (346)	315 (427)		460 (624)								
36 (49)	50 (68)	67 (91)	115 (156)	155 (210)	235 (319)	315 (427)	475 (644)	585 (793)		850 (1153)								

All figures are in foot-pounds (Newton-meters in parentheses) except those marked with an asterisk (*) which are inch-pounds (Newton-millimeters in parentheses). All of these values are for lubricated fasteners.

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ANSWERS

1. True. If enough of the hardened tip of the bit remains, the screwdriver can be reground and used again.

2. A *soft hammer*. Examples are lead, rawhide, plastic, brass, or rubber hammers.

3. False! Pliers are for *holding* work — not for loosening or tightening.

4. Pull — don't push .This will save your knuckles. (If you must push, use the base of your palm and keep your hand open.)

5. The offset allows more swing space in crowded places by "flopping" the wrench.

6. False. Adjustable wrenches should be placed on the nut so that the pulling force is applied only to the stationary jaw side of the wrench.

7. a-2-a; b-1-b.

8. 60 inch-pounds.

9. The bolt with a 6-dash head is higher in strength.

10. Because heat caused by friction with the grinding wheel will draw out the temper in the metal and soften it until useless.

11. File only on the forward or *pushing* stroke. Raise the file from the work on the return stroke to prevent damage to the teeth.

12. Hacksaw teeth should point *away* from the handle.

13. At least *two* teeth should always contact the material being sawed.

14. External pullers, internal pullers, and press-pullers.

15. A knife-edge pulling attachment. This will reach in behind the whole bearing and prevent ruining it.

16. Two metals are joined using a third metal as an adhesive. Unlike welding, soldering does not involve melting the two metals to be joined.

17. The number "6" means .006, or six-thousandths of an inch.

18. False. The micrometer should never be tightened so that the work cannot be drawn from between the anvil and spindle.

19. Add readings as follows:

.300
.025
.015
.004
Total = .344-inch

20. "PSI" means "pound per square inch." This is a unit of measure for liquid or air pressure. kPa means kilopascal. This is the metric unit of measure for liquid or air pressure.

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